AD-A248 387

Logistics Management Institute

A Profile of Defense Manufacturing Costs and Enabling Technologies

PL106RD1

Eric L. Gentsch
John W. McInnis

92-09070

LMI

92 4 08 041

January 1992

A Profile of Defense Manufacturing Costs and Enabling Technologies

PL106RD1

Eric L. Gentsch
John W. McInnis

Logistics Management Institute
6400 Goldsboro Road
Bethesda, Maryland 20817-5886

ACKNOWLEDGMENTS

This report contains the collaborative results of studies performed by the Logistics Management Institute under the direction of Eric L. Gentsch and by Thosani, Inc., under John W. McInnis, operating under separate contracts to the Cost/Technology Working Group of the Department of Defense Manufacturing Technology (ManTech) Task Force. The Task Force investigation was chartered by the Honorable Donald J. Yockey, Under Secretary of Defense (Acquisition).

The authors wish to thank the OSD and Service Manufacturing Technology staff for guidance and assistance in data collection.

REPORT DOCUMENTATION PAGE

Form Approved
OPM No. 0704-0188

1. AGENCY USE ONLY *(Leave Blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	Jan 92	Final

4. TITLE AND SUBTITLE
A Profile of Defense Manufacturing Costs and Enabling Technologies

5. FUNDING NUMBERS
C MDA903-90-C-0006
PE 0902198D

6. AUTHOR(S)
Eric L. Gentsch and John W. McInnis

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Logistics Management Institute
6400 Goldsboro Road
Bethesda, MD 20817-5886

8. PERFORMING ORGANIZATION REPORT NUMBER
LMI–PL106RD1

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Mr. Nicholas M. Torelli, Jr.
Deputy Assistant Secretary of Defense (Production Resources)
Room 3E813, The Pentagon
Washington, DC 20201

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
A: Approved for public release; distribution unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

In support of a DoD task force developing a strategic plan for the Manufacturing Technology (ManTech) Program, we surveyed 32 major acquisition programs representing 39 percent of the expected value of defense procurements between FY94 and FY03. We identified procurement costs by manufacturing processes and support activities and also identified manufacturing technologies that are required for the production of these systems. Based on these observations, we recommend strategies for the future focus of ManTech investments.

14. SUBJECT TERMS
Manufacturing technology; ManTech; Procurement costs

15. NUMBER OF PAGES
97

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	18. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL

LMI

Executive Summary

A PROFILE OF DEFENSE MANUFACTURING COSTS AND ENABLING TECHNOLOGIES

The DoD's Manufacturing Technology (ManTech) Program sponsors research aimed at developing advanced manufacturing processes for defense products. Concerned with optimizing the benefits of this program, Congress required DoD to develop a strategic plan for the allocation of ManTech investments. DoD formed a task force to respond to the congressional requirement. The task force sought to identify those manufacturing costs that are expected to consume the lion's share of defense procurements over the coming decade and those manufacturing technologies required for, or barriers to, effective weapons production. This information, combined with a long-term vision of defense manufacturing, would form the basis of the proposed strategic plan and would allow ManTech planners to pursue high payback opportunities in the associated production processes.

We developed a methodology for attributing procurement costs to manufacturing processes or associated support activities. Our analysis to identify high-cost manufacturing processes focused on 41 major acquisition programs that will represent 58 percent of the overall projected DoD procurement budget between FY94 and FY03. Thirty-two programs representing 39 percent of the DoD procurement budget provided data. Several observations emerged:

- Parts, subassemblies and material purchased from subcontractors and vendors represent 60 percent of the product cost.
- Manufacturing support activities including material handling, manufacturing engineering, production management, and other overhead costs account for approximately half the remaining cost, roughly equivalent to the cost of all traditional "hard" manufacturing processes combined.

Although the scope of our study did not allow collection of data on the 60 percent of manufacturing costs being performed by subtier suppliers, industry representatives believe that manufacturing support activities are at least as costly as materials transformation and assembly at both the prime and subcontractor level.

We also identified over 400 requirements for manufacturing technology to be developed across the programs surveyed. Approximately half of these manufacturing technology needs fall into nine categories:

- Composites fabrication
- Test and inspection techniques
- Electronics packaging
- Process control
- Alternatives to processes using hazardous materials
- Robotic applications
- Laser applications
- Precision machining
- Near-net-shape forming.

Analysis of the manufacturing technology needs shows they are skewed strongly toward materials transformation and assembly operations as compared to support activities.

To guide the ManTech strategic plan, we offer the following conclusions and recommendations:

- Since subtier vendors supply more than half the value added to DoD products, the ManTech Program should direct greater resources to this sector than it has done heretofore.
- Manufacturing support activities represent a significant cost that has not been adequately addressed by ManTech. Support activities span Service programs and are appropriate for the OSD portion of the ManTech Program.
- The Service's ManTech programs should continue to pursue the development of production technologies that enable increased weapon system performance, particularly those unique to each Service. The ManTech projects in the nine categories identified above should be coordinated across the Services.

CONTENTS

TABLES

FIGURES

CHAPTER 1

BACKGROUND

PURPOSE

The DoD's Manufacturing Technology (ManTech) Program sponsors research to develop advanced manufacturing processes needed for defense products. Investments in manufacturing technology have, with some exceptions, historically focused on resolving shop floor ("hard" technology) manufacturing problems encountered by a prime contractor in the course of producing weapon systems. Solving such problems improves producibility and reduces system acquisition costs. The solutions often can affect related systems as generic technical improvements are transferred across the defense sector. The DoD ManTech Task Force established the Cost/Technology Working Group to explore whether redirection of ManTech's historic focus would make the program more effective.

The Cost/Technology Working Group was tasked to identify strategic opportunities for ManTech investment in the major weapons that will be in production between FY94 and FY03. Our results and recommendations are among many inputs to the National Defense Manufacturing Technology Plan (NDMTP). Four working groups are contributing to the NDMTP. Recommendations of the Cost/Technology Working Group and those of the Vision Working Group, which is predicting manufacturing trends for the next 15 years and beyond, will help create a plan for allocation and coordination of ManTech funding in the coming decade. The Management Working Group is simultaneously refining the administrative procedures that implement ManTech strategy, including annual budgeting, project selection, and benefits tracking. Finally, the Technology Transfer Working Group is investigating the most effective means to disseminate the results of manufacturing research to program offices, defense industry, and, where applicable, to commercial industry.

APPROACH

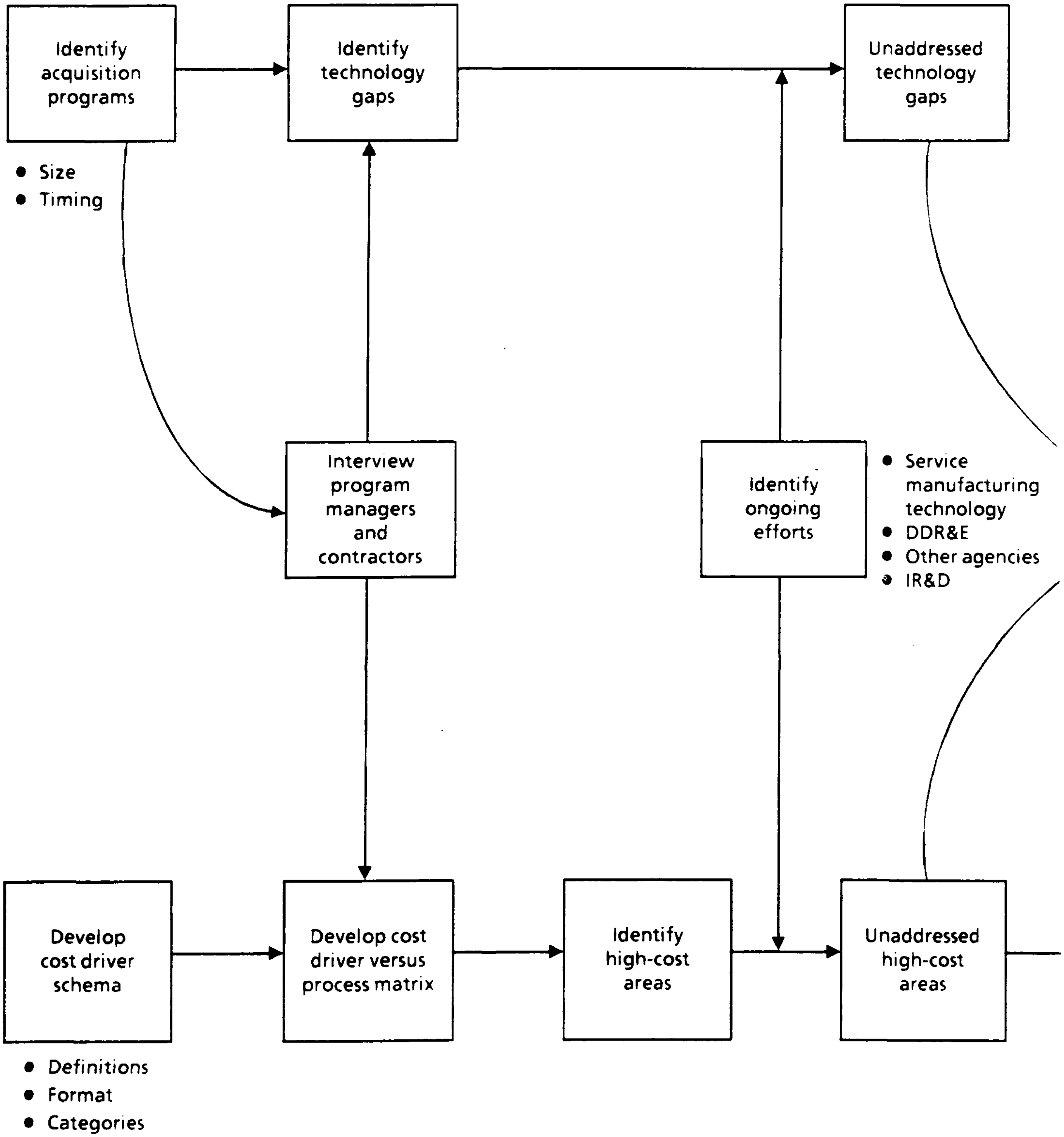
Central to the task is a logical approach within which ManTech investment decisions can be made and defended. A schematic of the approach we used is shown in

Figure 1-1. The approach is based upon the premise that the purpose of the ManTech program is two-fold: to reduce the acquisition and support costs of weapon systems and to develop technology that will allow advanced, higher performance systems to be built. The result is a profile of defense manufacturing consisting of two elements: the production activities that consume most major systems' procurement dollars, "the cost drivers," and the needed manufacturing technologies that are not yet available to produce those systems, the "ManTech gaps." These two elements provide complementary views of defense manufacturing. Being able to identify the manufacturing cost drivers allows DoD to actively pursue cost reduction. High-cost activities can be explored for opportunities where a relatively small ManTech investment could yield large cost reductions through automation, yield enhancement, or other improvements. Examining our list of ManTech gaps provides insight into the wide scope of product and process technologies required for defense manufacturing. The list of gaps can be compared to ManTech projects under way, to increase leveraging and avoid unnecessary duplication. Most importantly, the list is a starting point from which DoD can highlight manufacturing needs where a small investment can greatly enlarge industry's defense production capability.

The initial task was to identify the acquisition programs to be analyzed, based on the timing and dollar value of their production phases. We identified 41 programs that represent 58 percent of the overall DoD procurement budget of approximately $75 billion per year (this is the typical level of recent years – future procurements may be dramatically lower). These programs were not selected as a statistical sample, rather they represent the relatively few systems that will consume more than half of the money DoD spends for procurement. These programs are shown in Table 1-1.

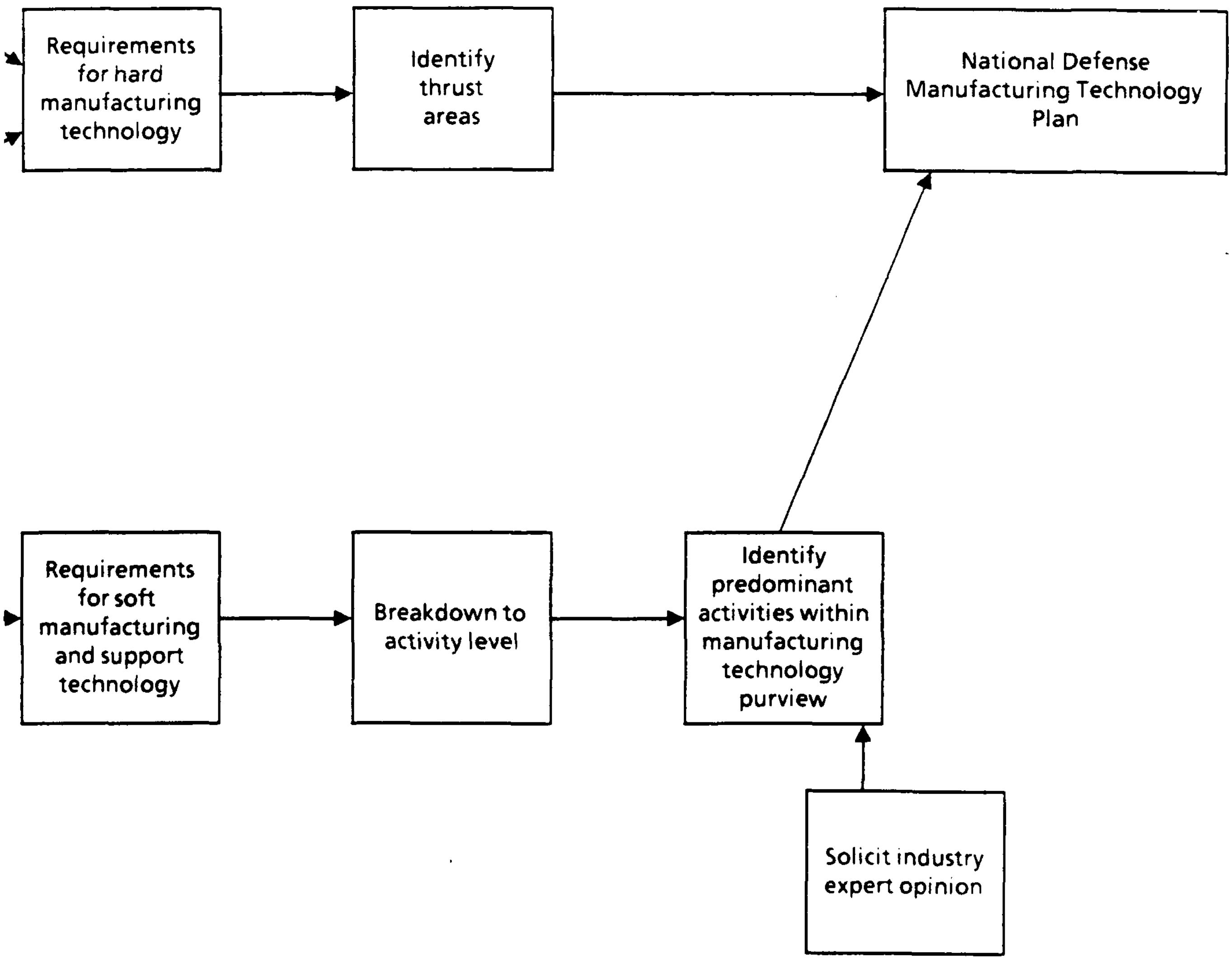
Next we solicited the process costs and technology gaps from the programs on our list. The request for data was transmitted through the Service ManTech executives to the Services' program offices. We developed and distributed a handbook that explained the data conventions and collection format.[1]

[1]LMI Handbook PL106 (unpublished). *National Defense Manufacturing Technology Plan: Process Cost Methodology*. Eric L. Gentsch. February 1991.



Note: DDR&E = Office of Director, Defense Research and Engineering; IR&D = independent research and development

FIG. 1-1. COST/TECHNOLOGY WC



NG GROUP STUDY APPROACH

TABLE 1-1

TARGET ACQUISITION PROGRAMS

Commodity	Service	Program[a]	Description
Aircraft	Army	***AH-64***	Apache attack helicopter
		Longbow	Apache fire-and-forget modification
		RAH-66	Comanche light attack helicopter
		UH-60	Blackhawk utility helicopter
	Navy	***F/A-18***	Hornet fighter/attack
		T-45	Goshawk trainer
	Air Force	B-2	Stealth bomber
		C-17	Transport
		E-8	Joint Surveillance and Target Attack Radar System
		F-16	Falcon fighter
		F-22	Lightning II fighter
		KC-135	Tanker engine modification
Missiles	Army	***AAWS-M***	Advanced Anti-Armor Weapon System – medium
		Hellfire	Helicopter-launched anti-armor missile
		LOS-R	Line-of-sight – Rear Air Defense System
		MLRS	Multiple Launch Rocket System
		MLRS-TGW	MLRS terminally guided weapon
		Patriot	Anti-aircraft/anti-missile point defense
	Navy	AAAM	Advanced air-to-air missile
		AIWS	Advanced Interdiction Weapon System
		MK-50	Torpedo
		SM-2	Standard missile – 2
	Air Force	ACM	Advanced cruise missile
		AMRAAM	Advanced medium-range anti-aircraft missile
		MILSTAR	Communications satellites
		Small	Intercontinental ballistic missile
		Titan IV	Space Launch System
Ships	Navy	***DDG-51***	Arleigh Burke class destroyer
		SSN-21	Seawolf class submarine
WTCV	Army	Abrams	M1 main battle tank
		Paladin	155mm self-propelled howitzer M109A6
Ammunition	Army	***SADARM***	Sense and destroy armor cluster munition
	Navy	***5-inch/54***	Naval gun shell
	Air Force	***CBU-87***	1,000 lb. cluster munition
Other	Army	***EPLRS***	Enhanced Position Location Reporting System
		FMTV	Family of medium tactical vehicles (trucks)
		MSE	Multiple subscriber equipment; battlefield communications
		PLS	Palletized Loading System
		SINCGARS	Single Channel Ground and Airborne Radio System
	Navy	***FDS***	Fixed Distributed System; undersea listening
	Air Force	GPS	Global Positioning System

Notes: WTCV = weapons and tracked combat vehicles; Other = mostly communications and electronics systems.

[a] Programs providing data to study are displayed in bold italics. The M-864 projectile and two Armament Enhancement Initiative programs were not targeted originally but provided data as well.

In order to identify process cost drivers, we developed a data form that was sent to the selected programs for completion. (See Figure 1-2.) The horizontal element of the matrix consists of a breakdown of the type of system (1b) into major subsystems along line 4 – airframe, propulsion, avionics, etc. – for aircraft. The vertical element is our generic taxonomy of manufacturing processes and includes purchased materials, several manufacturing processes, and several manufacturing support processes. The manufacturing process categories we have chosen represent a tradeoff between detail and cost of data collection. Many technologies comprise each category. (We list some examples for each in Appendix A.) As an example of the technologies within our categories, we show an "explosion" of electrical and electronics fabrication in Figure 1-3. Listing all manufacturing technologies would be virtually impossible, with new ones constantly being created as old ones become obsolete. The effort to determine the cost of each separate technology would be prohibitive and only of marginal value. Also, we use the term "support" process for lines 18, 19, and 20 rather than "overhead" because support activities are counted as direct costs or overhead costs depending on company practice.[2]

In each block of the matrix, then, the respondents entered the percentage of recurring production cost required by the specific process for the particular component. For example, mechanical forming might represent 2 percent of the airframe production cost for the F-16 aircraft.

The cost data for each system were weighted based upon the system's total cost versus the overall procurement budget and then aggregated into six major categories: aircraft, missiles, ships, weapons and tracked combat vehicles (WTCV), ammunition, and other items (largely communications). Finally, they were further aggregated into a single weighted category representative of all DoD hardware acquisitions. Analyses of these summary data led to the identification of manufacturing cost drivers.

Manufacturing technology gaps represent the second element of our manufacturing profile. ManTech gaps are barriers to the production of a defense product within its performance, cost, and schedule constraints. Locating ManTech

[2]Although we tried to be consistent across programs, in general we are not concerned with how manufacturing activities are charged by accountants. Rather, we are concerned with what the activities are, how much they cost, whether there are opportunities for improvement through the development of new technologies, and whether the activities are appropriate for ManTech investment.

1a. Program name	1b. Type of system	1c. Average unit cost 1d. Units in average
2a. Contractor	2b. Location	2c. Point of contact Name: Title: Phone:
3a. Prime/Sub (circle one)	3b. Major component(s) produced: CFE/GFE (circle one)	

4. WORK BREAKDOWN STRUCTURE							
5. Percent of unit cost							
SUBSYSTEM COST BREAKDOWN							
6. Purchased materials, components, and subassemblies							
MANUFACTURING PROCESSES							
7. M&S Forming							
8. M&S Treatment							
9. M&S Material Removal							
10. M&S Finishing							
11. M&S Joining							
12. M&S Assembly							
13. E&E Fabrication							
14. E&E Assembly							
15. Chemicals Processing							
16. Test/Inspection							
17. Other							
MANUFACTURING SUPPORT PROCESSES							
18. Materials Handling							
19. Manufacturing Engineering							
20. Production Management							
21. OTHER OVERHEAD							

Note: CFE = contractor-furnished equipment; GFE = Government-furnished equipment; M&S = mechanical and structural; E&E = electrical and electronic.

FIG. 1-2. DATA FORM

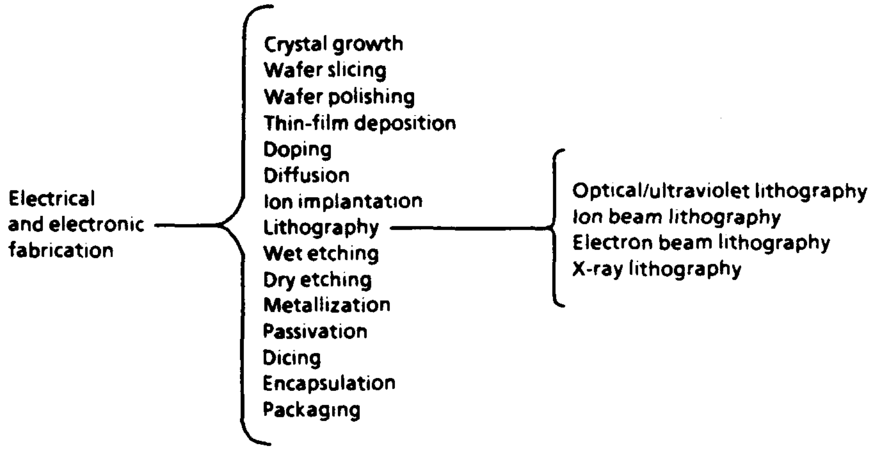


FIG. 1-3. ELECTRICAL AND ELECTRONIC FABRICATION TECHNOLOGIES

gaps also helps to identify opportunities for large cost reductions (i.e., ManTech investment payback) in process areas that are relatively cheap.

We requested ManTech gap information from the programs listed in Table 1-1. We also compiled gaps from the Service ManTech offices, from the Office of Director, Defense Research and Engineering (DDR&E), and from the SIMON data base.[3] We intended to collect information on both funded and unfunded processes.

The next chapter describes our findings and provides more detail on our approach.

[3] SIMON is a DoD on-line service that catalogs past and present ManTech projects.

CHAPTER 2

FINDINGS

We received data from the 32 major acquisition programs shown in Table 2-1 that are expected to represent 39 percent of DoD procurements for the period FY94 through FY03. Our data came from 8 aircraft programs, 10 missile programs, 2 ship programs, 1 WTCV program, 6 ammunition programs, and 5 "other" programs.[1]

In this section, we discuss our findings based on these data. First, we present the manufacturing cost data. We discuss follow-on studies we performed to learn more about the costs of purchased materials and the costs of manufacturing support activities. We then present the ManTech gaps. Finally, we compare the high-cost process areas to the ManTech gaps.

MANUFACTURING COST DRIVERS

Manufacturing costs are traditionally reported in three categories: materials, direct labor, and overhead. These categories, however, are of limited use in ManTech planning because they fail to specify which specific manufacturing activities, such as machining, assembly, or programming machine controllers, contribute to product cost. Also, as a manufacturer automates, overhead becomes large compared to direct labor; so large, in fact, that cost allocation based on direct labor presents a distorted picture of the cost required to produce a given product.

The nature of manufacturing costs required that we collect cost data in a manner that differs from traditional cost accounting. We asked that each of the programs complete the form shown in Figure 1-2. The form requires background information and cost information by cost category and subsystem (or work breakdown structure element). As an example, Table 2-2 shows the data submitted by the Patriot program. Appendix B contains a complete listing of the data sheets from all the programs.

[1]Approximately two-thirds of "other" programs, on a dollar basis, are communications and electronics systems.

TABLE 2-1

ACQUISITION PROGRAMS THAT PROVIDED DATA

Commodity	Service	Program
Aircraft	Army	AH-64 Longbow RAH-66 UH-60
	Navy	F/A-18 T-45
	Air Force	C-17 F-16
Missiles	Army	AAWS-M Hellfire LOS-R MLRS Patriot
	Navy	MK-50 SM-2
	Air Force	AMRAAM Small Titan IV
Ships	Navy	DDG-51 SSN-21
WTCV	Army	Paladin
Ammunition	Army	SADARM M-864 AEI HEAT AEI Kinetic
	Navy	5-inch/54
	Air Force	CBU-87
Other	Army	EPLRS MSE PLS SINCGARS
	Navy	FDS
Total		32

Notes: AEI = Armament Enhancement Initiative; Other = mostly communications and electronics systems.

TABLE 2-2

DATA COLLECTED FROM THE PATRIOT PROGRAM

(Percentage)

Cost elements	Propellant	G&C	Payload	Launch	Other
Work breakdown structure (WBS)					
Percent of unit cost	10	50	10	20	10
Subsystem cost breakdown					
Purchased materials	25	30	50	25	35
Manufacturing processes					
M&S forming		5	5	5	5
M&S treatment		5	5		5
M&S material removal					5
M&S finishing				5	5
M&S joining		5	5		5
M&S assembly		5		5	5
E&E fabrication		10		15	5
E&E assembly		10		15	5
Chemicals processing	15				
Test/inspection	5	5	5	5	
Other	5	5	5	5	5
Manufacturing support processes					
Materials handling	10	5	5	5	5
Manufacturing engineering	10	5	5	5	5
Production management	5	5	5	5	5
Other overhead	20	5	5	5	5
Not identified	5		5		
Subsystem totals	100	100	100	100	100

Note: E&E = electrical and electronic; G&C = guidance and control; M&S = mechanical and structural.

From each program's cost data, we compiled a weapon category summary, one each for aircraft, missiles, ships, WTCV, ammunition, and other systems. Finally, we combined all weapon system categories, weighted by their relative value of procurements, into a DoD procurement summary. Table 2-3 shows the share of defense procurement dollars going to each manufacturing cost element. The costs for weapon system categories (aircraft, missiles, etc.) have been weighted by their historical proportions, which are also shown in the table. We next discuss the DoD summary and then make some observations about the weapon system commodities.

Figure 2-1 displays the summary data of Table 2-3, sorted by relative cost. We can immediately make a number of observations from these data. Parts, subassemblies, and raw material represent most of the product cost. The value added by prime contractors typically is 40 percent; the remaining 60 percent of

TABLE 2-3

DISTRIBUTION OF DoD MANUFACTURING COSTS BY PROCESS AND COMMODITY

(Percentage)

Process	Commodity						Total commodities
	Aircraft	Missiles	Ships	WTCV	Ammu-nition	Other	
Parts	25.4	15.5	5.4	3.4	2.5	7.4	59.6
Forming	0.8	0.2	0.5	0.0	0.3	0.1	1.9
Treatment	0.0	0.1	0.1	0.0	0.1	0.0	0.3
Removal	0.7	0.5	0.4	0.2	0.2	0.1	2.1
Finishing	0.1	0.1	0.4	0.1	0.1	0.0	0.8
Joining	0.1	0.1	0.7	0.1	0.3	0.0	1.4
Assembly	1.7	0.5	1.2	0.2	0.3	0.3	4.1
Electronics fabrication	0.0	0.6	0.0	0.0	0.0	0.0	0.7
Electronics assembly	0.0	0.7	0.3	0.1	0.1	1.1	2.3
Chemicals processing	0.0	0.1	0.1	0.0	0.0	0.0	0.2
Inspection	0.6	1.0	0.8	0.1	0.2	0.6	3.4
Other	1.1	0.5	0.0	0.1	0.1	0.0	1.8
Material handling	0.4	0.5	0.8	0.2	0.1	1.0	3.1
Manufacturing engineering	0.6	1.5	1.2	0.1	0.1	0.9	4.4
Production management	0.6	0.9	1.3	0.1	0.1	0.7	3.7
Other overhead	2.8	2.3	1.7	0.2	0.4	2.6	10.0
Total	35.0	25.0	15.0	5.0	5.0	15.0	100.0

Note: Sample results extended to total DoD procurement, weighted by the typical historical proportions of each individual commodity.

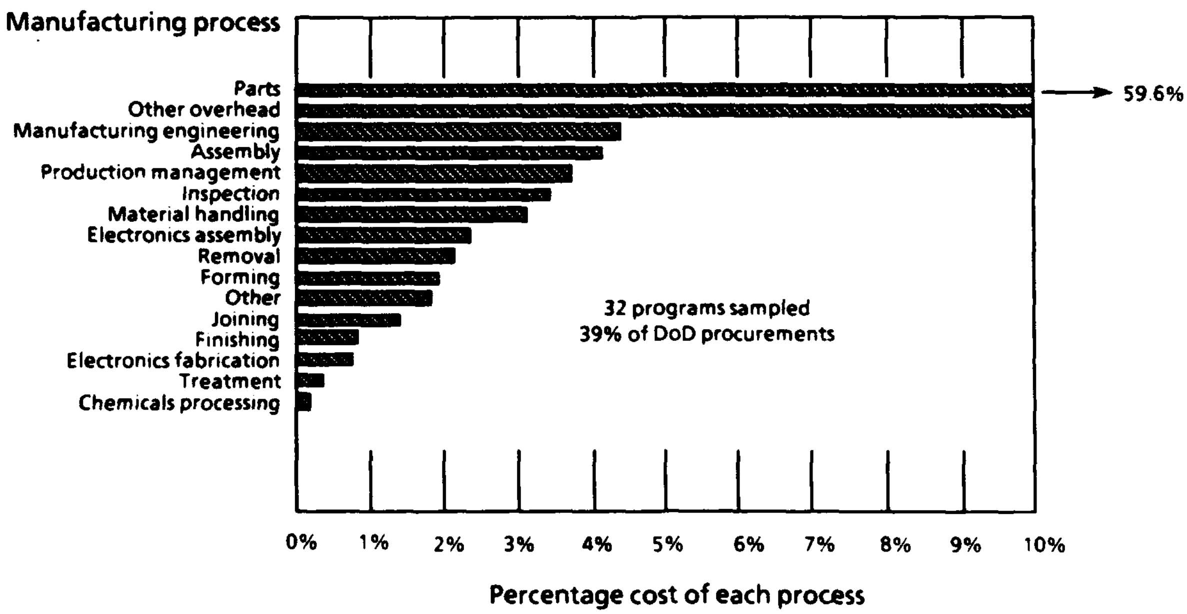


FIG. 2-1. DoD MANUFACTURING COST PROFILE – ALL COMMODITIES

manufacturing value is added at lower tiers. Manufacturing support activities – production management, manufacturing engineering, materials handling, and other overhead – account for slightly more than half of the remaining cost. In fact, support activity cost is roughly equal to the cost of all traditional direct labor process costs combined.

Figures 2-2 through 2-7 display the data from each weapon system commodity of Table 2-3. For these figures we have normalized the data in Table 2-3 to 100 percent for each commodity. We also show the size of our sample for each commodity. For example, we surveyed 8 aircraft programs that together will represent 19.5 percent of DoD procurements (see Figure 2-2); all aircraft programs typically represent 35 percent of DoD procurements as shown in the Table 2-3 row labeled "Total."

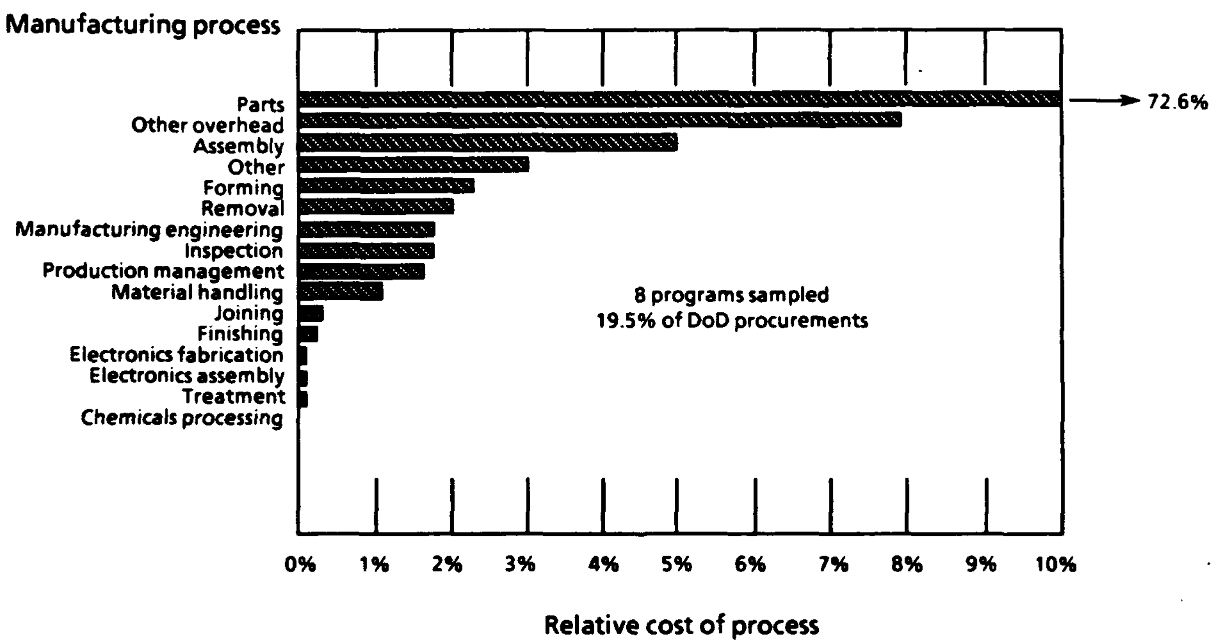


FIG. 2-2. DoD AIRCRAFT MANUFACTURING COST PROFILE

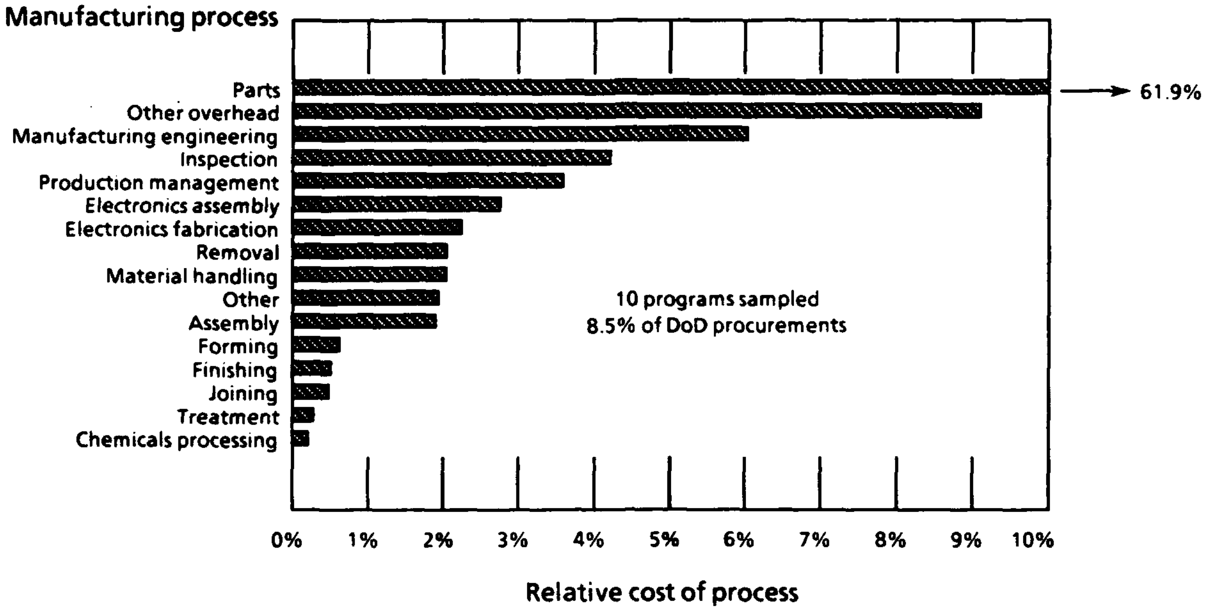


FIG. 2-3. DoD MISSILE MANUFACTURING COST PROFILE

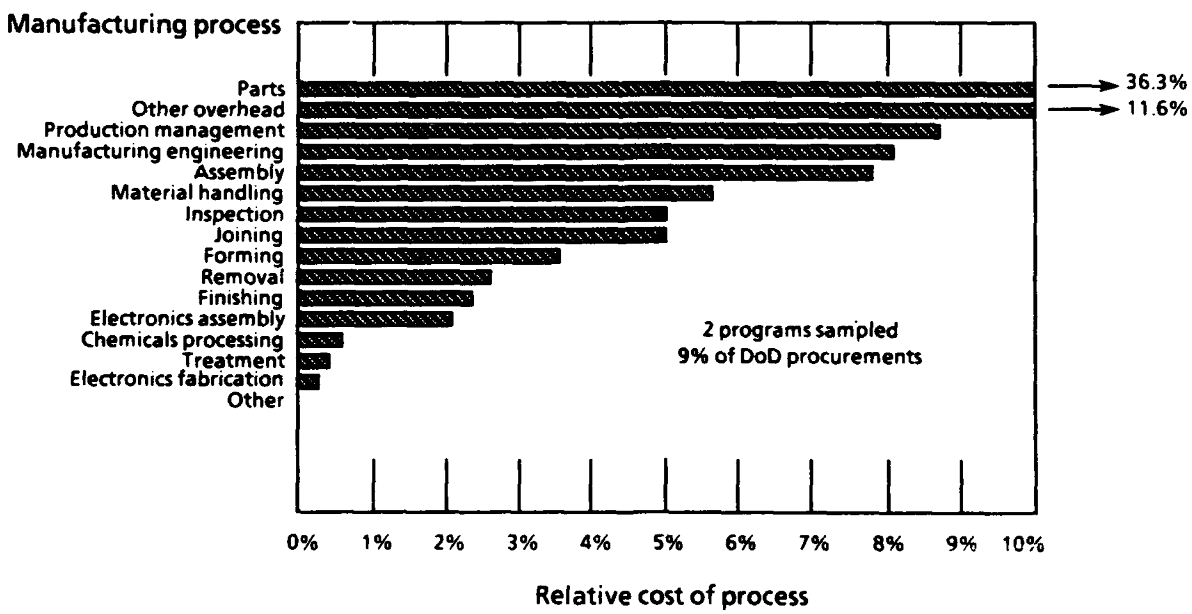


FIG. 2-4. DoD SHIP MANUFACTURING COST PROFILE

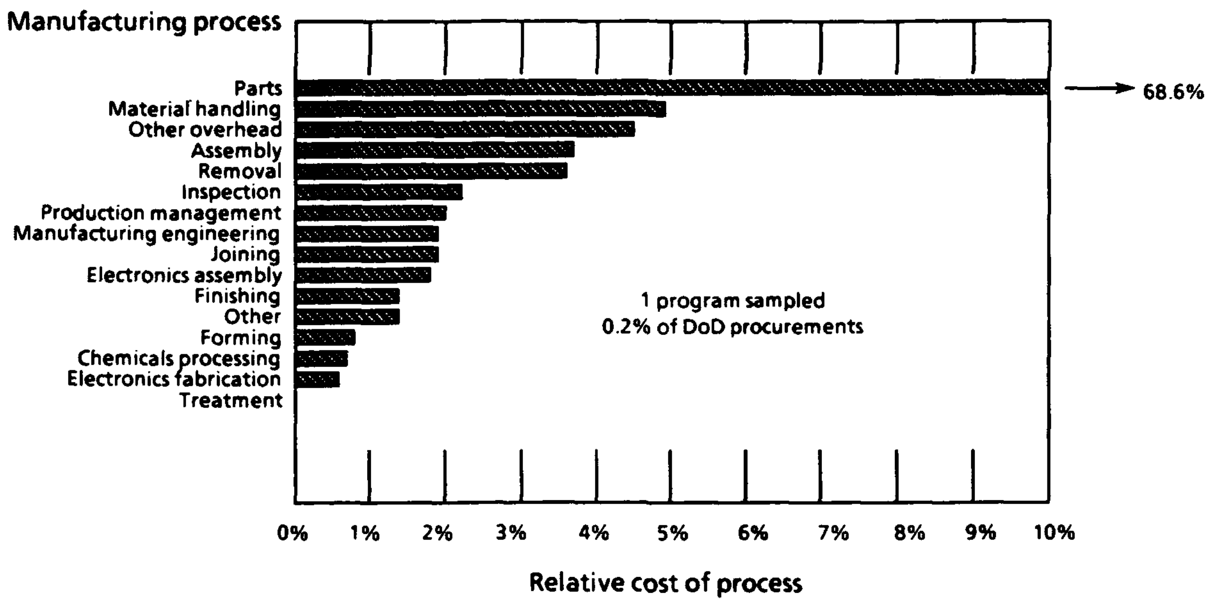


FIG. 2-5. DoD WEAPONS AND TRACKED COMBAT VEHICLES MANUFACTURING COST PROFILE

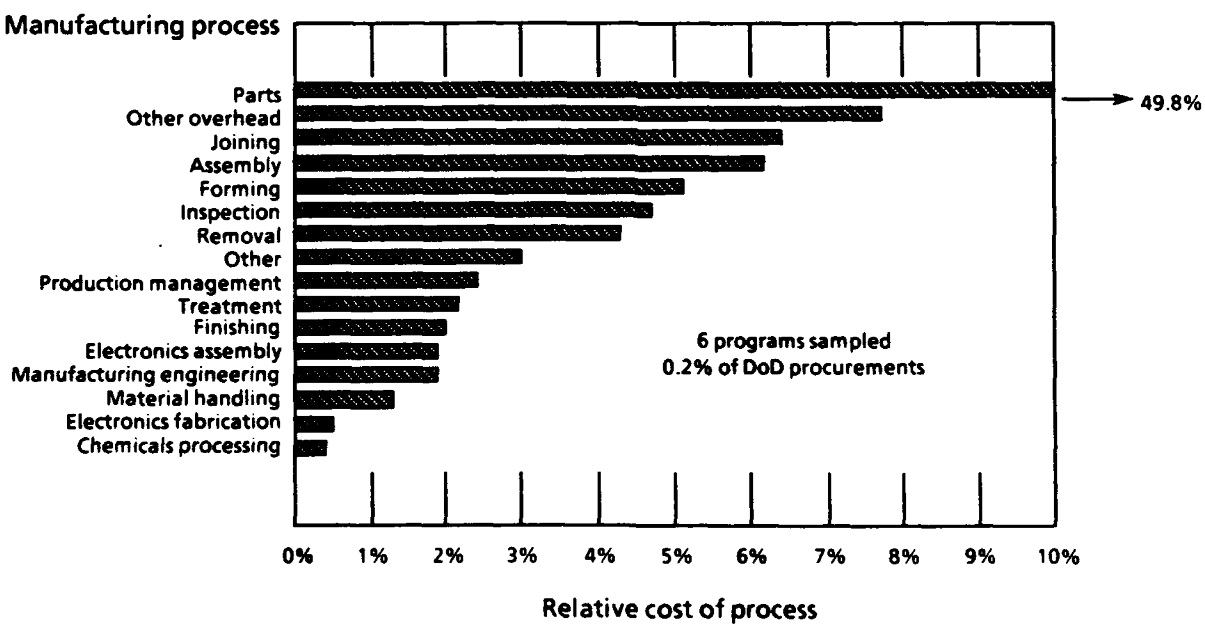


FIG. 2-6. DoD AMMUNITION MANUFACTURING COST PROFILE

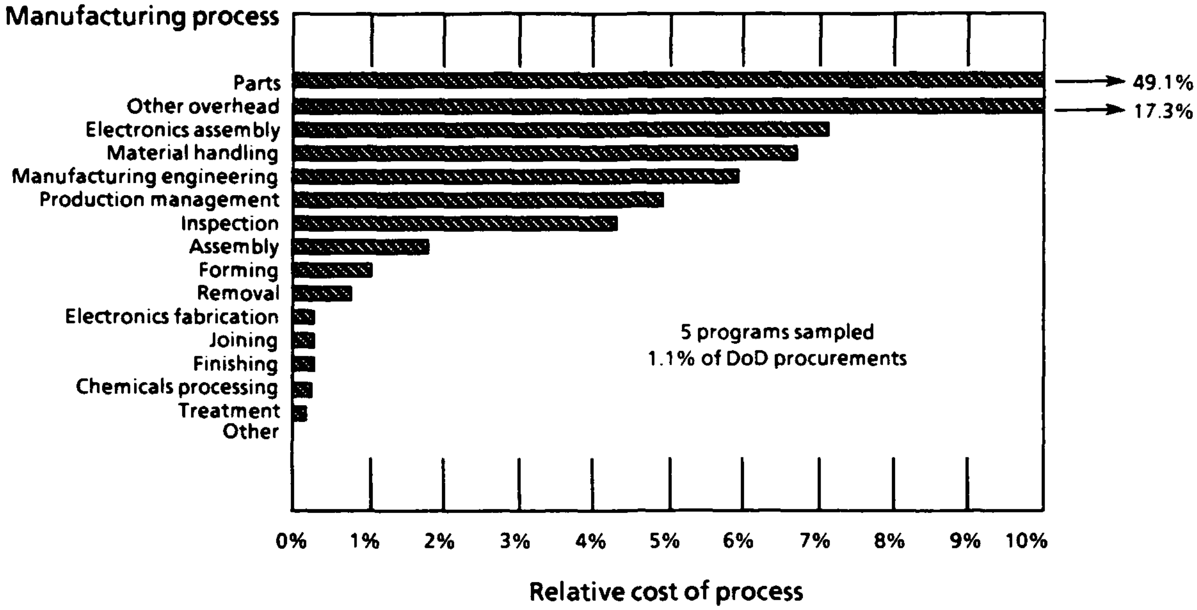


FIG. 2-7. DoD "OTHER" ITEMS MANUFACTURING COST PROFILE
(Mostly communications and electronics systems)

As in summary Figure 2-1, manufacturing support activities rank high in the costs of the individual weapon systems. There are variations between categories in the relative costs of unit manufacturing processes. For example, we observe that assembly, forming, material removal, and "other" processes rank high in aircraft manufacture (see Figure 2-2). These results are expected and largely reflect the work required to build and assemble the airframe. In missile production, we see that inspection, electronics assembly, and electronics fabrication rank high (see Figure 2-3). Ship production, as might be expected, shows that production management, assembly, and material handling dominate costs (see Figure 2-4). Finally, two-thirds of the procurements for "other" items are for communications and electronics systems (see Figure 2-7). We might, therefore, expect this category to be dominated by electronics, assembly, and inspection costs. The unit processes dominating the production cost are electronic assembly, inspection, and mechanical assembly. We are somewhat surprised that electronics fabrication does not rank high, but it is hard to make inferences from this observation, because the "other" items category includes items as diverse as trucks, hand-held radios, and satellites.

Referring again to Figure 2-1, the summary cost data, we repeat that purchased material consumes 60 percent of production-phase procurement dollars. These represent parts and subassemblies purchased by the primes and top-level subcontractors that were polled by the program offices during our data collection. Had we been able to collect data from lower tiers, which would have increased the study effort substantially, more and more of this cost category would have been allocated to the remaining manufacturing and support activities. At some point, only raw materials (ores, petroleum, etc.) would remain.

As an alternative to collecting more subtier data from our weapon programs, we asked the question, "If we were to know all the subtier cost data, would it change our manufacturing cost profile? Specifically, would the manufacturing support activities no longer dominate?" We asked this question of defense industry experts at the Aerospace Industries Association (AIA) and the Electronics Industries Association (EIA). The AIA and EIA agreed that additional data would not change our basic finding that other overhead, manufacturing engineering, and production management costs are generally equal to or greater than those of the manufacturing unit processes collectively. The associations did caution, however, that at small businesses, support costs are much lower than at the medium and large companies.

The EIA provided additional data on subtier production costs for typical military electronics products. Of the purchased materials category, which is 60 percent of total procurements, 19 percent of total procurements, or about one-third, is spent for electronic components. The EIA's cost breakdown for these electronic components is shown in Figure 2-8. As expected, the portion of cost spent for purchased materials is smaller (34 percent). Manufacturing support activities continue to consume a large 41 percent share. For electronics, then, manufacturing support seems to dominate production costs for both prime and subcontractors.

Referring again to Figure 2-1, the summary cost data, "other overhead," manufacturing engineering, and production management are the cost drivers of DoD major systems' production. To provide more information on these categories to the ManTech community, we sought to identify their constituent components and the typical relative magnitudes of each constituent cost. We consulted experts in

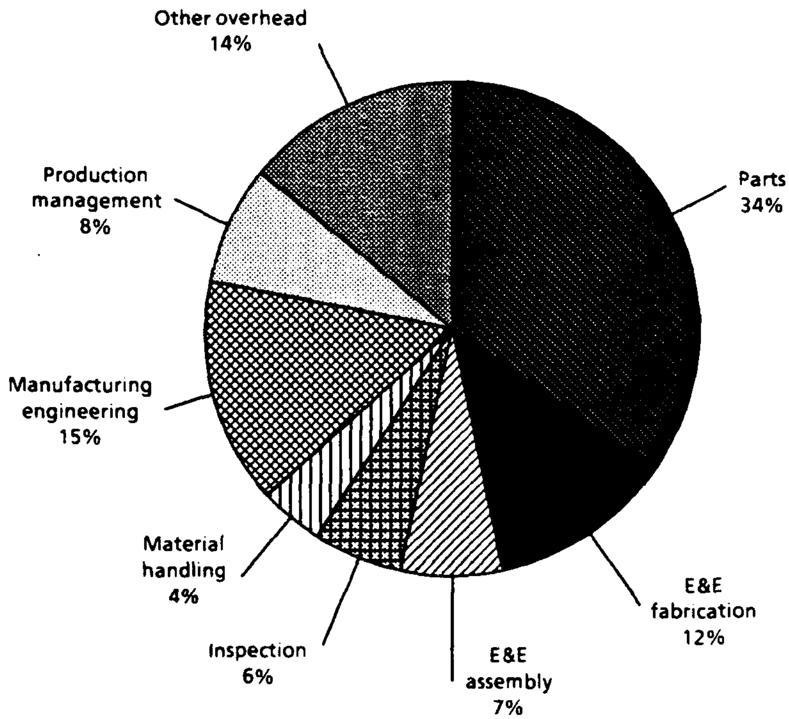


FIG. 2-8. COST BREAKDOWN OF ELECTRONICS PURCHASED PARTS

defense, industry, and research organizations.[2] Table 2-4 lists the components of manufacturing support costs (and includes materials handling, the other support category) and sorts the costs into the accounting categories that are generally used to report them. The support activity cost components are not homogeneous. For example, while kitting is a tangible activity, depreciation is not. Support costs may or may not relate directly to a physical process and, accordingly, may or may not be suitable targets for ManTech investments. We have labeled those support activities in Table 2-4 that might be appropriate for ManTech investment.

Since each company sets up its own accounting system within broadly acceptable standards, it is impractical to determine the exact magnitudes of these cost components. We can, however, rank them in relation to one another. In Table 2-5, we list the experts' consensus of the nine most costly support activities. Of the high-cost support activities, the experts were most vocal regarding the adoption

[2]We consulted the Defense Logistics Agency, the EIA, the National Security Industry Association, the Industrial Technology Institute, Computer-Aided Manufacturing – International, the AIA, and the National Center for Manufacturing Sciences.

TABLE 2-4

BREAKOUT OF TYPICAL MANUFACTURING SUPPORT ACTIVITIES BY TYPICAL ACCOUNTING CATEGORY

Accounting category	Manufacturing support activity			
	Other overhead	Manufacturing engineering	Production management	Materials handling
General overhead	Management[a] Facilities[a] Depreciation[a] Supplies Fringe benefits Materials planning[a]			
Material burden				Receiving[a] Inspection[a] Kitting[a] Warehousing[a] Distribution (internal)[a] Purchasing[a]
Manufacturing overhead		Manufacturing technical support – manufacturing engineering, industrial engineering, quality engineering, etc.[a] Tool design[a] Manufacturing data center[a]	Factory supervision[a] Production planning, inventory control, expediting, dispatching[a] Tool management[a] Equipment maintenance[a]	Production stores and distribution[a]
Engineering overhead (recurring)		Engineering management Engineering data center[a] Lab support Engineering technical support (designers, draftsmen, analysts) Product qualification (value engineering, specifications, standards, etc.)[a]		
General and administrative	Personnel Legal Accounting[a] Bid and proposal Independent research and development			Transportation (external)[a]

[a] Activity (or activity creating this cost) that might be appropriate for ManTech funding.

TABLE 2-5

PREDOMINANT SUPPORT ACTIVITIES

Support activity	Typical accounting category
Purchasing	Material burden
Manufacturing engineering Production planning Equipment maintenance Computer integrated manufacturing	Manufacturing overhead
Computer-aided design Technical training	Engineering overhead
Accounting Environmental issues[a]	General and administrative

[a] Although not included in our indirect cost matrix, environmental issues were listed as critical by several of the respondents.

of activity-based accounting and improving manufacturing engineering, production planning, and information integration. While all agreed that the adoption of activity-based accounting was appropriate, there was disagreement on whether this is an appropriate area for ManTech investment. In manufacturing engineering, all agreed that the manufacturing interface with design, so-called "design for manufacturing and assembly" should be emphasized. Somewhat to our surprise, the experts also cited the need to improve production planning and scheduling systems. We did not expect this because of the number of commercial systems that have become available in the past decade. The experts also agreed that factory information services hold much potential for overall cost reduction. The integration of engineering design and analysis data bases with process planning, accounting, maintenance, personnel, and other support data bases remains a challenge to industry.

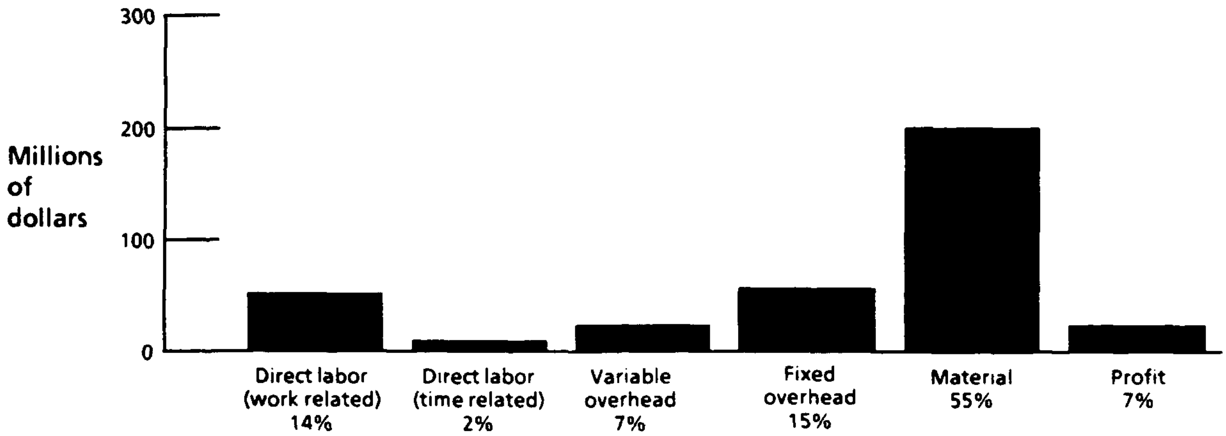
Two other opinions of the experts warrant comment. One expert stressed the need to improve the technology at small manufacturers to the point where the overhead topics in Table 2-5 "take center stage." This hints at the importance of the relationship between developmental programs, like ManTech, and implementational programs, such as DoD's Industrial Modernization Incentives Program. It also emphasizes the importance of technology transfer. Also, several experts raised the issue of manufacturing facilities complying with environmental regulations as an increasing component of cost.

The Naval Seas Systems Command has provided an example of an initiative aimed at reducing manufacturing support costs. The goal of this initiative was to "examine naval ship construction processes and to develop recommendations for reducing the cost and schedule of ship construction while meeting or exceeding product quality."[3] The major assumption underlying this initiative was that the current cost collection method using a work breakdown structure (common to all defense industries) does not provide a good measure of shipbuilding efficiency, and that better measurement criteria would indicate areas where dramatic improvements are possible.

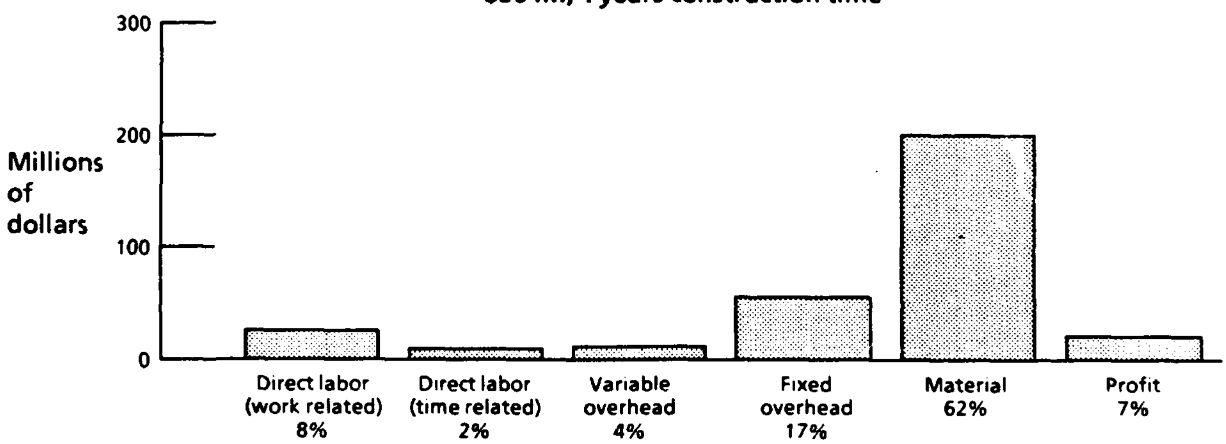
Figure 2-9 shows an analysis of ship construction cost and schedule factors. Bar graph (a) shows current practice. Bar graph (b) shows the effect on cost of applying automation and reducing direct labor by half. Bar graph (c) shows the effect on cost if the ship could be built in 2 years, rather than 4, with the same total number of man-hours. Reducing construction time results in dramatically better savings than reducing direct labor man-hours. The additional cost reduction occurs because of a smaller allocation of fixed overhead and lower material carrying charges, both indirect costs. Reducing construction time effectively increases the capacity of the facilities being used. True cost savings are only realized when the excess capacity is liquidated or production volumes increased to absorb total overhead.

After further analysis, the Navy developed a ship construction strategy called product-oriented construction, a term for building a ship as a series of interim products, rather than system by system. The benefit to this strategy is shown in Figure 2-10. On-unit efficiency (i.e., construction of a complete product, such as an engine room) is four to six times more efficient and therefore faster than on-block construction (i.e., construction within a hull structural "block"). The set of metrics developed by the Navy is shown as Figure 2-11. These metrics lead to the recognition of time as a critical cost driver and, ultimately, to the reduction of construction support and overhead areas as a primary cost-reduction measure.

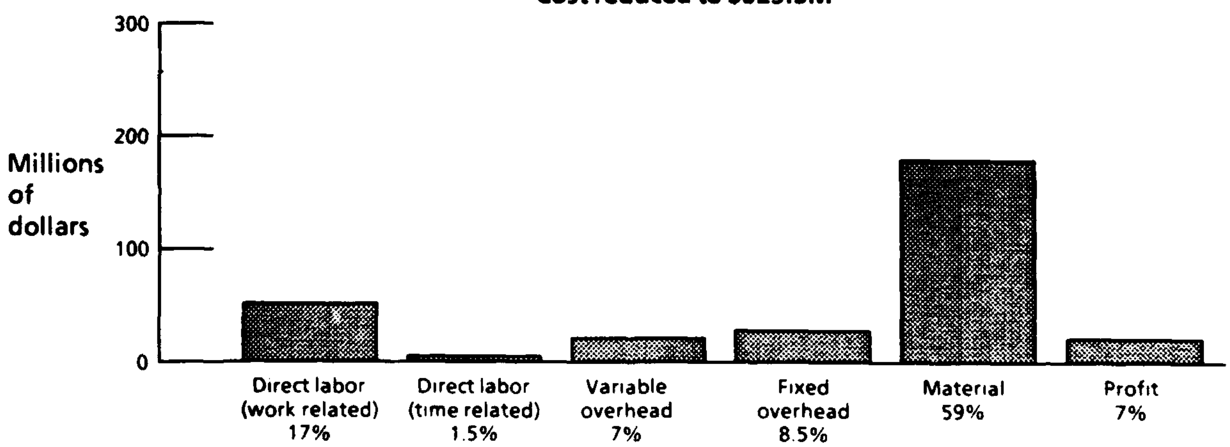
[3]From *Ship Construction Team*, unpublished report of U.S. Naval Sea Systems Command, David Taylor Research Center, Carderock, Md.



(a)
Hypothetical ship: Current practice
$364M, 4 years construction time



(b)
Same ship: 50% less labor
Cost reduced to $323.5M



(c)
Same ship: 50% less time
Cost reduced to $305.5M

FIG. 2-9. SHIPBUILDING COST COMPARISON

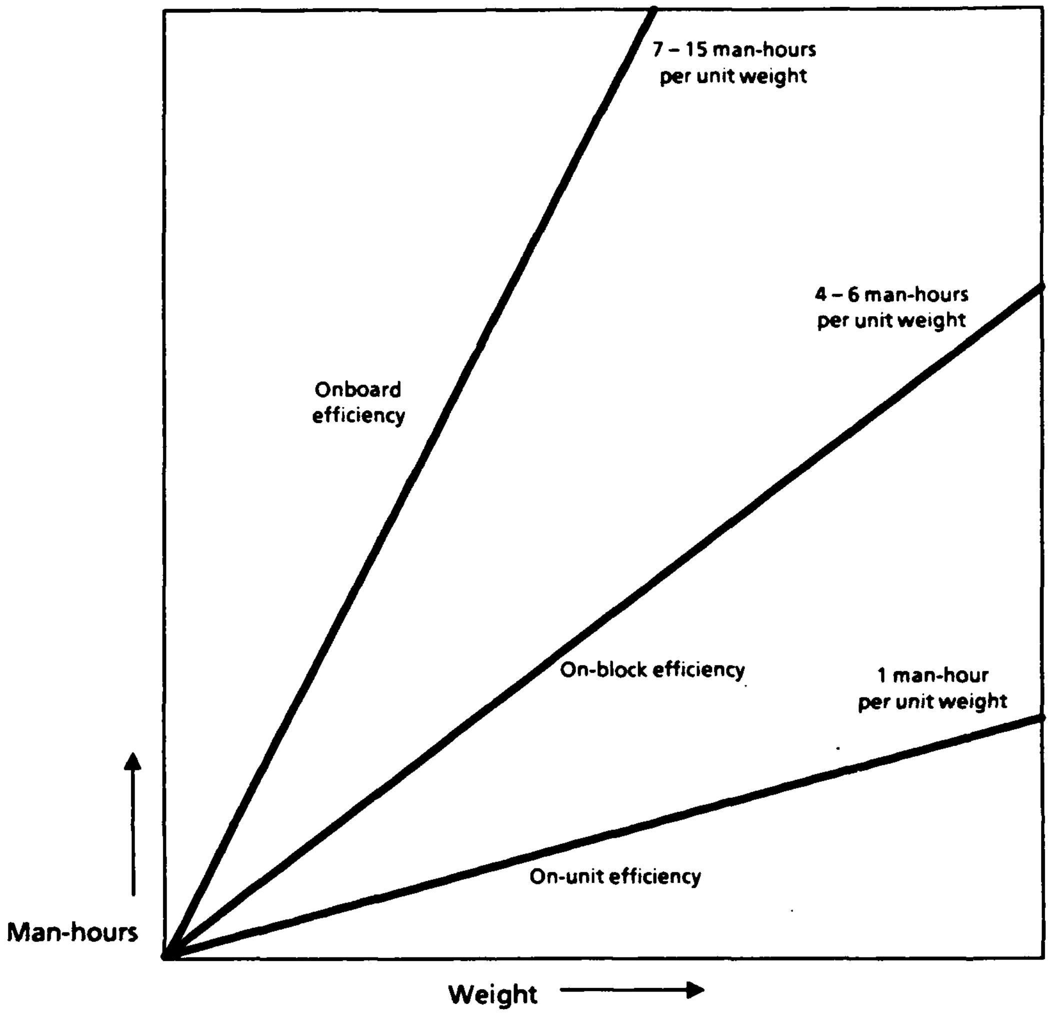


FIG. 2-10. OUTFIT STAGE EFFICIENCIES

Extent to which product-oriented construction is applied

Efficient – % outfit complete at keel laying

– % outfitting on unit

– % outfitting on block

Inefficient – % outfitting onboard

FIG. 2-11. SHIP CONSTRUCTION PERFORMANCE MEASURES

MANUFACTURING TECHNOLOGY GAPS

Our data collection yielded over 400 ManTech gaps. We collected these data from program managers, the ManTech offices in each Service, DDR&E, and the SIMON data base. We categorized these technology gaps by the process they affected and the primary commodity for which the deficiency was noted. A summary listing of all 400 ManTech gaps, sorted by their primary process and commodity, is presented in Appendix D. We recognize that many of the ManTech gaps can apply to more than one process and more than one type of weapon, and, therefore, that such a categorization should be viewed with some caution. This approach, as discussed later, allowed us to compare these ManTech gaps to the process cost drivers.

A review of the ManTech gap listing reveals that about 200 are currently funded by ManTech and about 200 are unfunded. In another view, almost half of the gaps (181) can be grouped into nine thrust areas. A thrust area is a product, process, or technology grouping that might be convenient for cross-Service/OSD coordination. Table 2-6 shows these thrust areas as well as the number of funded and unfunded issues identified in each. These are the thrust areas:

- *Composites fabrication.* Composite materials combine a high-strength reinforcement in an environmentally protective matrix and are used for high-strength, low-weight components and low-observable components. Composites are classified by their matrix materials – metal, ceramic, or polymer.

- *Test and inspection techniques.* Some inspection will always be necessary in manufacturing and to diagnose repairs. The inspection techniques being developed have wide application and are based on automated, nondestructive techniques. This thrust complements the process control thrust (discussed below), which attempts to reduce the amount of inspection required by improving first-pass quality.

- *Electronics packaging.* Electronics packaging means assembling integrated circuits and discrete devices onto circuit boards and modules. This includes providing structural integrity, environmental protection, electrical interconnection, and heat dissipation. The technology has progressed from through-hole mounting to surface mounting; multichip modules are being developed.

- *Process control.* Many weapon system components are made from materials and designs that have (to date, at least) little commercial application. Therefore, the data bases that relate production parameters (such as feeds and speeds for machining metals) to design specifications are incomplete.

TABLE 2-6

CANDIDATE MANTECH THRUST AREAS

Thrust area	Number of ManTech gaps resulting from survey		
	Total	Funded	Unfunded
Composites fabrication	53	21	32
Test and inspection techniques	34	18	16
Electronics packaging	30	12	18
Process control	17	13	4
Alternative to hazard materials	15	2	13
Robotic applications	10	8	2
Laser applications	9	3	6
Precision machining	7	3	4
Near-net-shape forming	6	3	3

Production parameters are often determined by trial and error. This frequently produces poor yields and low throughput. Two approaches are being pursued to enhance process control: to study the science of manufacturing processes and to develop *in situ* sensors that provide closed loop feedback to process equipment controls.

- *Alternatives to processes using hazardous materials.* Many manufacturing processes require materials that are hazardous and whose disposal is controlled. Examples include beryllium powder and semiconductor etching agents. There are many efforts underway to use these materials more safely and to dispose of them in accordance with current regulations. Control is only a stop-gap and some materials will eventually be banned. Alternatives to manufacturing processes that rely on these materials will have to be developed.

- *Robotic applications.* The potential of robots in repetitive or hazardous jobs is widely appreciated. The factors limiting robot application have been the sensory and software systems. New developments in these areas can expand the use of robots in emerging high-volume/variable-product flexible manufacturing systems.

- *Laser applications.* Industrial lasers are being applied to material removal, joining, inspection, handling, and other uses. Laser technology for dual-use processes is generally available from the commercial sector but may have to be customized for defense manufacturing.

- *Precision machining.* Precision machining and forming is the reliable and repeatable production of discrete parts within design specifications and the reduction of dimensional variations. Included in this thrust are machine controller technology and process-sensing technology.

- *Near-net-shape forming.* Near-net-shape forming is casting and molding, primarily of plastics and powdered metals, into shapes that require very little machining to reach finished dimensions.

COST DRIVER/MANTECH GAP COMPARISON

The distribution of ManTech gaps is skewed toward hard manufacturing processes. Relatively few gaps were identified in the support activities of manufacturing engineering, production management, materials handling, and other overhead. This is not surprising since the purpose of searching for ManTech gaps was to identify measures that increase product performance rather than reduce cost.

Table 2-7 overlays our cost driver results and our ManTech gap results in a single manufacturing process/weapon system commodity matrix. This comparison identifies opportunities that have not been addressed and, therefore, are primary candidates for ManTech attention. Areas of interest are elements with high cost and elements with large numbers of ManTech gaps. We have circled those boxes with a cost of greater than 1 percent or more than 10 ManTech gaps. Both of these are arbitrary thresholds. Only three boxes overlap the high-cost and the ManTech gap thresholds (those three are marked with bold circles). Put another way, few technical challenges and cost-reduction opportunities have been identified for the high-cost processes; the technical challenges and cost-reduction opportunities that have been identified are in low-cost processes.[4]

[4]Our use of the term "low-cost" should not be confused with "cost-efficient."

TABLE 2-7

MANUFACTURING COST/MANTECH GAP OVERLAY

Process	Aircraft	Missiles	Ships	WTCV	Ammunition	Other	Total
Parts	25.4%	15.5%	5.4%	3.4%	2.5%	7.4%	59.6%
Forming	0.8%	0.2%	0.5%	0.0%	0.3%	0.1%	1.9%
	46	18	8	3	2	3	80
Treatment	0.0%	0.1%	0.1%	0.0%	0.1%	0.0%	0.3%
	2	1					3
Removal	0.7%	0.5%	0.4%	0.2%	0.2%	0.1%	2.1%
	5		6	1	1		13
Finishing	0.1%	0.1%	0.4%	0.1%	0.1%	0.0%	0.8%
	11	9	1	7	1		29
Joining	0.1%	0.1%	0.7%	0.1%	0.3%	0.0%	1.4%
	4	1	9	2	1	1	18
Assembly	1.7%	0.5%	1.2%	0.2%	0.3%	0.3%	4.1%
	7	1	3		1		12
Electronics fabrication	0.0%	0.6%	0.0%	0.0%	0.0%	0.0%	0.7%
	16	24	4		1		45
Electronics assembly	0.0%	0.7%	0.3%	0.1%	0.1%	1.1%	2.3%
	15	16	9		1	11	52
Chemicals processing	0.0%	0.1%	0.1%	0.0%	0.0%	0.0%	0.2%
	4	4			7	3	18
Inspection	0.6%	1.0%	0.8%	0.1%	0.2%	0.6%	3.4%
	10	10	3	5	3	11	42
Other	1.1%	0.5%	0.0%	0.1%	0.1%	0.0%	1.8%
	10	5				39	54
Material handling	0.4%	0.5%	0.8%	0.2%	0.1%	1.0%	3.1%
			1				1
Manufacturing engineering	0.6%	1.5%	1.2%	0.1%	0.1%	0.9%	4.4%
	5	2	1		1	1	8
Production management	0.6%	0.9%	1.3%	0.1%	0.1%	0.7%	3.7%
				1		1	2
Other overhead	2.8%	2.3%	1.7%	0.2%	0.4%	2.6%	10.0%
						5	5
Total	35.0%	25.0%	15.0%	5.0%	5.0%	15.0%	100.0%

Note: Top box: portion of DoD procurements consumed by this element; bottom box: number of ManTech gaps identified for this element.

CHAPTER 3

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

Based on our observations and findings, we draw the following conclusions.

A significant portion of manufacturing for DoD is done by subtier suppliers. Because purchased parts account for over 50 percent of major weapon system costs, and because our survey covered prime contractors (and, in some cases, first-tier subcontractors), manufacturing activity at subtier suppliers accounts for at least half of DoD's major program manufacturing costs.

At the upper tiers, manufacturing support is at least as important a cost driver as the manufacturing processes themselves. The sum of manufacturing engineering, production management, materials handling, and other overhead costs is a slightly greater portion (21 percent) of production costs than the sum of the hard processes (19 percent).

With some exceptions, manufacturing support is a cost driver at lower tiers as well as at prime contractors. Our study showed that the support component of typical military electronics products is a cost driver at lower tiers. We caution, however, that very small firms tend to have low support costs and, for them, the conclusion may be invalid.

The cost reduction of support activities is best viewed from an enterprise perspective. Although we do not know the exact cost breakdown of manufacturing support activities, we can say with some confidence that a ManTech development that positively affects several of the activities is preferred to an investment that affects only a single activity. This, then, requires a focus at an enterprise level rather than at an individual activity level.

The distribution of ManTech gaps is skewed strongly toward hard manufacturing processes as compared to manufacturing support activities. Most ManTech gaps are in forming, mechanical assembly, electronics fabrication, and electronics assembly: those primarily relating to the production of aircraft and missiles. Note also that these gaps tend to be concentrated in areas of relatively low cost (the areas may be performance drivers but are not cost drivers).

RECOMMENDATIONS

Our task was to identify strategic opportunities for ManTech investment in the major acquisition programs that will be in production between FY94 and FY03. The purpose of the ManTech program is twofold: to reduce the acquisition and support costs of weapon systems and to develop technology to enable advanced systems to be built. We offer the following recommendations to guide ManTech toward these goals:

- *Strengthen subtier impact.* Since subtier manufacturers supply more than half the value added to DoD products, the ManTech program should direct greater resources to this sector than previously.

- *Study manufacturing support activities.* Manufacturing support activities represent a significant cost that might be reduced through judicious ManTech investments. However, the requirements (and payoffs) for traditional ManTech investments remain high and should not be sacrificed or reallocated. Rather, cost reduction of manufacturing support activities should be pursued through incremental ManTech funding.

- *OSD's role.* Manufacturing support costs span Service programs and are the sphere in which the OSD portion of the ManTech program should operate. The reduction of these costs has not been a traditional pursuit of ManTech. While our cost breakdown is still too aggregate to identify specific cost reduction opportunities, the functions performed tend to cross product and program lines and, therefore, offer a common opportunity across the Services that is independent of any individual Service agenda.

- *Service roles.* The Services' ManTech programs should continue to pursue their traditional roles of developing enabling technologies in support of weapon system production, with emphasis on the thrust areas identified in our findings. Technical committees might be formed for these thrusts. These committees could then be tasked with identifying, through industry interaction, the best technical developments that would satisfy the corresponding ManTech gaps. This process is relatively close to the traditional ManTech Advisory Group subcommittee functions, with the important exception that the committee would now be given a closed set of issues in a confined, clearly identified thrust area.

APPENDIX A

MANUFACTURING PROCESS CATEGORIES

MANUFACTURING PROCESS CATEGORIES

MECHANICAL AND STRUCTURAL FORMING

Casting	Explosive forming
Forging	Electrohydraulic forming
Extruding	Magnetic forming
Rolling	Electroforming
Drawing	Powdered metal forming
Squeezing	Cold isostatic pressing
Swaging	Hot isostatic pressing
Bending	Thermoplastic plastics molding
Shearing	Thermoset plastics curing
Spinning	Composites weaving
Stretch forming	Composites layup
Roll forming	Filament winding

MECHANICAL AND STRUCTURAL TREATMENT

Heat treating

Hot working

Cold working

Shot peening

Annealing

MECHANICAL AND STRUCTURAL MATERIAL REMOVAL

Traditional	Nontraditional
Turning	Ultrasonic
Planing	Electrical discharge
Shaping	Electro-arc
Drilling	Laser cutting
Tapping	Electrochemical
Boring	Chem-milling
Reaming	Abrasive jet cutting
Sawing	Electron beam machining
Broaching	Plasma-arc machining
Milling	
Grinding	
Hobbing	
Routing	

MECHANICAL AND STRUCTURAL FINISHING

Polishing
Barrel tumbling
Plating
Honing
Lapping
Superfinishing
Metal spraying
Inorganic coating
Anodizing
Plasma spraying
Sputtering
Painting

MECHANICAL AND STRUCTURAL JOINING

Welding

Laser welding

Soldering

Brazing

Sintering

Adhesive joining

MECHANICAL AND STRUCTURAL ASSEMBLY

Manual assembly

Screw and bolt fastening

Riveting

Pressing

Plugging

ELECTRICAL AND ELECTRONIC FABRICATION

Crystal growth

Wafer slicing

Wafer polishing

Thin-film deposition

Doping

Diffusion

Ion implantation

Lithography

- Optical/ultraviolet lithography
- Ion beam lithography
- Electron beam lithography
- X-ray lithography

Wet etching

Dry etching

Metallization

Passivation

Dicing

Encapsulation

Packaging

ELECTRICAL AND ELECTRONIC ASSEMBLY

Through-hole mounting

Wave soldering

Surface mounting

Cabling

Wire harnessing

CHEMICALS PROCESSING

Blending

Pelletizing

Chipping

Packaging

TEST/INSPECTION

Geometric

Mechanical

Electrical

Thermal

Chemical

APPENDIX B

MANUFACTURING COST DATA BY PROGRAM

AH-64 APACHE

Process cost coverage = 41%   Average unit cost = 13.8 ($M)

WORK BREAKDOWN STRUCTURE	Airframe	Prop.	Avionics	Armt	Other
Percent of unit cost	53%	14%	23%	1%	9%
SUBSYSTEM COST BREAKDOWN					
PURCHASED MATERIALS	50%	68%	70%	50%	65%
MANUFACTURING PROCESSES					
M&S Forming	2%	0%			1%
M&S Treatment	1%	1%		1%	0%
M&S Material Removal	1%	4%	2%	8%	1%
M&S Finishing	1%	1%		1%	1%
M&S Joining	1%	1%			0%
M&S Assembly	6%	2%	3%	2%	5%
E&E Fabrication		0%	3%		
E&E Assembly		0%	4%		
Chemicals Processing	1%	0%		1%	1%
Test/Inspection	2%	2%	0%	2%	2%
Other	1%		5%	1%	0%
MANUFACTURING SUPPORT PROCESSES					
Materials Handling	2%	3%	1%	2%	1%
Manufacturing Engineering	5%	5%	3%	5%	4%
Production Management	2%	5%	2%	2%	1%
OTHER OVERHEAD	26%	7%	7%	26%	18%
Subsystem Totals	100%	100%	100%	100%	100%

LONGBOW (APACHE MOD)

Process cost coverage = 51%

Average unit cost = 3.8413 ($M)

WORK BREAKDOWN STRUCTURE	Airframe	Prop.	Avionics	Armt.	Other
Percent of unit cost	27%	2%	38%	11%	22%
SUBSYSTEM COST BREAKDOWN					
PURCHASED MATERIALS	30%	50%	53%	50%	65%
MANUFACTURING PROCESSES					
M&S Forming	1%				1%
M&S Treatment	1%	1%			1%
M&S Material Removal		1%	2%	1%	1%
M&S Finishing		1%		1%	1%
M&S Joining	1%			1%	1%
M&S Assembly	12%	10%	2%	7%	
E&E Fabrication			1%		1%
E&E Assembly			8%	1%	
Chemicals Processing					
Test/Inspection	2%	2%	3%	4%	3%
Other	4%				
MANUFACTURING SUPPORT PROCESSES					
Materials Handling	1%	1%	9%	1%	1%
Manufacturing Engineering	3%	3%	9%	3%	3%
Production Management	5%	5%	4%	5%	5%
OTHER OVERHEAD	40%	26%	9%	26%	26%
Subsystem Totals	100%	100%	100%	100%	109%

LH

Process cost coverage = 3%   Average unit cost = 15.1 ($M)

WORK BREAKDOWN STRUCTURE	Airframe	Prop.	Avionics	Armt.	Other
Percent of unit cost	24%	6%	41%	4%	25%
SUBSYSTEM COST BREAKDOWN					
PURCHASED MATERIALS	100%	50%	100%	100%	100%
MANUFACTURING PROCESSES					
M&S Forming		1%			
M&S Treatment		0%			
M&S Material Removal		5%			
M&S Finishing		0%			
M&S Joining		1%			
M&S Assembly		5%			
E&E Fabrication		0%			
E&E Assembly		0%			
Chemicals Processing		0%			
Test/Inspection		5%			
Other		0%			
MANUFACTURING SUPPORT PROCESSES					
Materials Handling		8%			
Manufacturing Engineering		4%			
Production Management		4%			
OTHER OVERHEAD		16%			
Subsystem Totals	100%	100%	100%	100%	100%

UH-60 BLACKHAWK

Process cost coverage = 37%   Average unit cost = 6.67 ($M)

WORK BREAKDOWN STRUCTURE	Airframe	Prop.	Avionics	Other	Armt
Percent of unit cost	48%	33%	3%	16%	
SUBSYSTEM COST BREAKDOWN					
PURCHASED MATERIALS	54%	57%	67%	100%	
MANUFACTURING PROCESSES					
M&S Forming	2%	0%			
M&S Treatment	1%	1%			
M&S Material Removal	5%	5%			
M&S Finishing	2%	2%			
M&S Joining	5%	2%			
M&S Assembly	7%	2%			
E&E Fabrication		0%	2%		
E&E Assembly		0%	5%		
Chemicals Processing		1%			
Test/Inspection	2%	3%			
Other	0%				
MANUFACTURING SUPPORT PROCESSES					
Materials Handling	3%	4%	1%		
Manufacturing Engineering	2%	8%	4%		
Production Management	3%	7%	1%		
OTHER OVERHEAD	14%	7%	20%		
Subsystem Totals	100%	100%	100%	100%	

F/A-18

Process cost coverage = 38%   Average unit cost = 20.9 ($M)

WORK BREAKDOWN STRUCTURE	Airframe	Avionics	Prop.	Armt.
Percent of unit cost	65%	17%	17%	1%
SUBSYSTEM COST BREAKDOWN				
PURCHASED MATERIALS	42%	100%	100%	100%
MANUFACTURING PROCESSES				
M&S Forming	9%			
M&S Treatment				
M&S Material Removal	6%			
M&S Finishing				
M&S Joining				
M&S Assembly	20%			
E&E Fabrication				
E&E Assembly				
Chemicals Processing				
Test/Inspection	10%			
Other				
MANUFACTURING SUPPORT PROCESSES				
Materials Handling	3%			
Manufacturing Engineering	3%			
Production Management	8%			
OTHER OVERHEAD				
Subsystem Totals	100%	100%	100%	100%

T-45

Process cost coverage = 64%

Average unit cost = 15.18 ($M)

	Airframe	Prop.	Other
WORK BREAKDOWN STRUCTURE			
Percent of unit cost	64%	20%	16%
SUBSYSTEM COST BREAKDOWN			
PURCHASED MATERIALS		100%	100%
MANUFACTURING PROCESSES			
M&S Forming	12%		
M&S Treatment			
M&S Material Removal			
M&S Finishing			
M&S Joining			
M&S Assembly	23%		
E&E Fabrication			
E&E Assembly			
Chemicals Processing			
Test/Inspection	7%		
Other	58%		
MANUFACTURING SUPPORT PROCESSES			
Materials Handling			
Manufacturing Engineering			
Production Management			
OTHER OVERHEAD			
Subsystem Totals	100%	100%	100%

C-17

Process cost coverage = 26%　　　Average unit cost = 290 ($M)

WORK BREAKDOWN STRUCTURE	Airframe	Prop	Avionics	Mat'l	Other
Percent of unit cost	31%	12%	5%	41%	11%
SUBSYSTEM COST BREAKDOWN					
PURCHASED MATERIALS	15%	100%	100%	100%	100%
MANUFACTURING PROCESSES					
M&S Forming	0%				
M&S Treatment					
M&S Material Removal	6%				
M&S Finishing	1%				
M&S Joining	1%				
M&S Assembly	10%				
E&E Fabrication	0%				
E&E Assembly	0%				
Chemicals Processing					
Test/Inspection					
Other	0%				
MANUFACTURING SUPPORT PROCESSES					
Materials Handling	4%				
Manufacturing Engineering	4%				
Production Management	4%				
OTHER OVERHEAD	53%				
Subsystem Totals	100%	100%	100%	100%	100%

F-16

Process cost coverage = 58% Average unit cost = 14.4 ($M)

WORK BREAKDOWN STRUCTURE	Airframe	Prop.	Avionics	Arm't.	Other
Percent of unit cost	44%	21%	13%	5%	17%
SUBSYSTEM COST BREAKDOWN					
PURCHASED MATERIALS	50%	13%	100%	100%	
MANUFACTURING PROCESSES					
M&S Forming	2%	38%			
M&S Treatment	0%				
M&S Material Removal	1%	36%			
M&S Finishing	0%				
M&S Joining	1%				
M&S Assembly	9%	7%			
E&E Fabrication	2%				
E&E Assembly					
Chemicals Processing					
Test/Inspection	3%	5%			
Other	2%				
MANUFACTURING SUPPORT PROCESSES					
Materials Handling	4%				
Manufacturing Engineering	22%				
Production Management	4%				
OTHER OVERHEAD					100%
Subsystem Totals	100%	100%	100%	100%	100%

AAWS-M

Process cost coverage = 31%

Average unit cost = 0.0209 ($M)

WORK BREAKDOWN STRUCTURE	Seeker	Guidance	Warhead	Prop	Control	Launch	Container
Percent of unit cost	32%	33%	11%	5%	8%	9%	3%
SUBSYSTEM COST BREAKDOWN							
PURCHASED MATERIALS	58%	69%	58%	91%	91%	82%	91%
MANUFACTURING PROCESSES							
M&S Forming							
M&S Treatment							
M&S Material Removal	4%	6%	5%				
M&S Finishing	0%		2%				
M&S Joining						1%	
M&S Assembly	0%	0%	3%			3%	
E&E Fabrication		5%	4%			1%	
E&E Assembly	3%	3%	14%			3%	
Chemicals Processing							
Test/Inspection	4%	4%	5%			2%	
Other	22%						
MANUFACTURING SUPPORT PROCESSES							
Materials Handling	2%	2%	1%	1%	1%	1%	1%
Manufacturing Engineering	2%	3%	3%	3%	3%	3%	3%
Production Management	4%	6%	6%	5%	5%	5%	5%
OTHER OVERHEAD							
Subsystem Totals	98%	98%	100%	100%	100%	100%	100%

HELLFIRE

Process cost coverage = 47%

Average unit cost =0.034764 ($M)

WORK BREAKDOWN STRUCTURE	Seeker	Payload	G&C	Prop.
Percent of unit cost	45%	13%	32%	10%
SUBSYSTEM COST BREAKDOWN				
PURCHASED MATERIALS	51%	72%	43%	70%
MANUFACTURING PROCESSES				
M&S Forming				
M&S Treatment				
M&S Material Removal				
M&S Finishing				
M&S Joining				
M&S Assembly		5%	8%	
E&E Fabrication	18%		15%	7%
E&E Assembly				
Chemicals Processing				
Test/Inspection	3%	1%	4%	1%
Other				
MANUFACTURING SUPPORT PROCESSES				
Materials Handling	4%	5%	3%	5%
Manufacturing Engineering	8%	2%	10%	2%
Production Management	2%	1%	3%	1%
OTHER OVERHEAD	14%	14%	14%	14%
Subsystem Totals	100%	100%	100%	100%

LOS-R

Process cost coverage = 18%   Average unit cost = 1.2 ($M)

WORK BREAKDOWN STRUCTURE	HMMWV	Turret	Launch	Missile
Percent of unit cost	4%	56%	16%	25%
SUBSYSTEM COST BREAKDOWN				
PURCHASED MATERIALS	100%	67%	100%	100%
MANUFACTURING PROCESSES				
M&S Forming				
M&S Treatment				
M&S Material Removal				
M&S Finishing		1%		
M&S Joining		2%		
M&S Assembly		3%		
E&E Fabrication		1%		
E&E Assembly		4%		
Chemicals Processing				
Test/Inspection		5%		
Other				
MANUFACTURING SUPPORT PROCESSES				
Materials Handling		3%		
Manufacturing Engineering		3%		
Production Management		3%		
OTHER OVERHEAD		8%		
Subsystem Totals	100%	100%	100%	100%

MLRS

Process cost coverage = 21% Average unit cost = 1.2 ($M)

WORK BREAKDOWN STRUCTURE	Base	Turret	Cage	Elec.	Assy
Percent of unit cost	5%	7%	33%	4%	52%
SUBSYSTEM COST BREAKDOWN					
PURCHASED MATERIALS	78%	84%	74%	46%	85%
MANUFACTURING PROCESSES					
M&S Forming					
M&S Treatment					
M&S Material Removal					
M&S Finishing	0%		0%	0%	0%
M&S Joining			0%	2%	
M&S Assembly	4%	2%	5%	3%	1%
E&E Fabrication				1%	
E&E Assembly		0%	0%	7%	0%
Chemicals Processing					
Test/Inspection	2%	1%	3%	9%	1%
Other					
MANUFACTURING SUPPORT PROCESSES					
Materials Handling	2%	1%	3%	7%	1%
Manufacturing Engineering	1%	1%	2%	3%	1%
Production Management	3%	2%	4%	11%	2%
OTHER OVERHEAD	9%	9%	9%	9%	9%
Subsystem Totals	100%	100%	100%	100%	100%

PATRIOT

Process cost coverage = 69%

Average unit cost = 0.65 ($M)

WORK BREAKDOWN STRUCTURE	Prop.	G&C	Payload	Launch	Other
Percent of unit cost	10%	50%	10%	20%	10%
SUBSYSTEM COST BREAKDOWN					
PURCHASED MATERIALS	25%	30%	50%	25%	35%
MANUFACTURING PROCESSES					
M&S Forming		5%	5%	5%	5%
M&S Treatment		5%	5%		5%
M&S Material Removal					5%
M&S Finishing				5%	5%
M&S Joining		5%	5%		5%
M&S Assembly		5%		5%	5%
E&E Fabrication		10%		15%	5%
E&E Assembly		10%		15%	5%
Chemicals Processing	15%				
Test/Inspection	5%	5%	5%	5%	
Other	5%	5%	5%	5%	5%
MANUFACTURING SUPPORT PROCESSES					
Materials Handling	10%	5%	5%	5%	5%
Manufacturing Engineering	10%	5%	5%	5%	5%
Production Management	5%	5%	5%	5%	5%
OTHER OVERHEAD	20%	5%	5%	5%	5%
Subsystem Totals	95%	100%	95%	100%	100%

MK-50 TORPEDO

DATA NOT SHOWN

COMPETITION SENSITIVE

STANDARD MISSILE

Process cost coverage = 60%   Average unit cost = 0.237 ($M)

WORK BREAKDOWN STRUCTURE	Round	Guid.	Pilot	Steer	Dorsals
Percent of unit cost	2%	57%	29%	5%	7%
SUBSYSTEM COST BREAKDOWN					
PURCHASED MATERIALS	2%	40%	50%	30%	15%
MANUFACTURING PROCESSES					
M&S Forming					32%
M&S Treatment					4%
M&S Material Removal		10%	15%	20%	2%
M&S Finishing	2%	2%	2%	2%	3%
M&S Joining					2%
M&S Assembly	60%	4%	5%	8%	
E&E Fabrication		6%			
E&E Assembly	5%	5%	2%	4%	5%
Chemicals Processing			2%	1%	
Test/Inspection	15%	15%	10%	8%	4%
Other		5%			4%
MANUFACTURING SUPPORT PROCESSES					
Materials Handling	5%	5%	2%	2%	6%
Manufacturing Engineering	2%	2%	2%	10%	6%
Production Management	1%	2%	5%	5%	7%
OTHER OVERHEAD	8%	4%	5%	10%	10%
Subsystem Totals	100%	100%	100%	100%	100%

AMRAAM

Process cost coverage = 23%

Average unit cost = 0.52 ($M)

WORK BREAKDOWN STRUCTURE	Control	Warhead	Motor	Guid.
Percent of unit cost	12%	2%	5%	81%
SUBSYSTEM COST BREAKDOWN				
PURCHASED MATERIALS	79%	100%	100%	75%
MANUFACTURING PROCESSES				
M&S Forming	1%			
M&S Treatment				
M&S Material Removal	1%			
M&S Finishing				
M&S Joining				
M&S Assembly	3%			
E&E Fabrication				1%
E&E Assembly				4%
Chemicals Processing				
Test/Inspection	3%			4%
Other				2%
MANUFACTURING SUPPORT PROCESSES				
Materials Handling				
Manufacturing Engineering	10%			10%
Production Management	3%			4%
OTHER OVERHEAD				
Subsystem Totals	100%	100%	100%	100%

SMALL ICBM

Process cost coverage = 22%   Average unit cost = 1.002 ($M)

	Prop	G&C	Payload	Launch	Basing
WORK BREAKDOWN STRUCTURE					
Percent of unit cost	12%	26%	8%	10%	44%
SUBSYSTEM COST BREAKDOWN					
PURCHASED MATERIALS	30%	100%	64%	100%	76%
MANUFACTURING PROCESSES					
M&S Forming	0%		0%		0%
M&S Treatment	0%				0%
M&S Material Removal	3%		1%		4%
M&S Finishing	1%		1%		0%
M&S Joining	1%		1%		1%
M&S Assembly	15%		5%		4%
E&E Fabrication			0%		0%
E&E Assembly	2%		3%		2%
Chemicals Processing	6%		0%		0%
Test/Inspection	10%		4%		1%
Other	2%				1%
MANUFACTURING SUPPORT PROCESSES					
Materials Handling	4%		5%		
Manufacturing Engineering	6%		7%		12%
Production Management	8%		4%		
OTHER OVERHEAD	12%		5%		
Subsystem Totals	99%	100%	100%	100%	100%

DATA NOT SHOWN

PROPRIETARY

DATA NOT SHOWN

DRAFT – ADVANCE COPY

PALADIN

Process cost coverage = 31%

Average unit cost = 1.076 ($M)

WORK BREAKDOWN STRUCTURE	Turret	Chassis	I&A	Other
Percent of unit cost	9%	30%	29%	32%
SUBSYSTEM COST BREAKDOWN				
PURCHASED MATERIALS	44%	48%	65%	98%
MANUFACTURING PROCESSES				
M&S Forming	9%			
M&S Treatment				
M&S Material Removal		10%	2%	
M&S Finishing	2%	4%		
M&S Joining	8%	4%		
M&S Assembly	5%	7%	4%	
E&E Fabrication			2%	
E&E Assembly		3%	3%	
Chemicals Processing	1%	1%	1%	
Test/Inspection	2%	2%	5%	
Other	2%	2%	2%	
MANUFACTURING SUPPORT PROCESSES				
Materials Handling	5%	8%	5%	2%
Manufacturing Engineering	2%	3%	3%	
Production Management	3%	3%	3%	
OTHER OVERHEAD	17%	5%	5%	
Subsystem Totals	100%	100%	100%	100%

SADARM

Process cost coverage = 37%

Average unit cost =0.014452 ($M)

WORK BREAKDOWN STRUCTURE	Elec	Sensor	Lethal	Carrier	DDO&S	Other
Percent of unit cost	40%	23%	7%	6%	8%	16%
SUBSYSTEM COST BREAKDOWN						
PURCHASED MATERIALS	58%	64%	71%	69%	58%	68%
MANUFACTURING PROCESSES						
M&S Forming						
M&S Treatment						
M&S Material Removal						
M&S Finishing						
M&S Joining						
M&S Assembly				8%	11%	2%
E&E Fabrication						
E&E Assembly	12%	8%				
Chemicals Processing						
Test/Inspection	2%	0%			0%	
Other						
MANUFACTURING SUPPORT PROCESSES						
Materials Handling						
Manufacturing Engineering	5%	5%	6%		8%	7%
Production Management	8%	8%	8%	8%	8%	8%
OTHER OVERHEAD	15%	15%	15%	15%	15%	15%
Subsystem Totals	100%	100%	100%	100%	100%	100%

5"/54 AMMO

Process cost coverage = 68%

Average unit cost =0.000388 ($M)

WORK BREAKDOWN STRUCTURE	Body	Adapter	Load	Fuze	Assy
Percent of unit cost	34%	7%	28%	18%	13%
SUBSYSTEM COST BREAKDOWN					
PURCHASED MATERIALS	30%	12%	60%	20%	2%
MANUFACTURING PROCESSES					
M&S Forming	13%			5%	
M&S Treatment	3%			1%	
M&S Material Removal	20%	37%		3%	
M&S Finishing	2%	2%		1%	
M&S Joining	1%				
M&S Assembly				25%	
E&E Fabrication					
E&E Assembly					
Chemicals Processing			5%		
Test/Inspection	4%	12%	1%	10%	
Other			20%	8%	84%
MANUFACTURING SUPPORT PROCESSES					
Materials Handling	3%	2%	2%	2%	2%
Manufacturing Engineering	4%	15%	1%	5%	1%
Production Management	5%	5%	1%	5%	1%
OTHER OVERHEAD	15%	15%	10%	15%	10%
Subsystem Totals	100%	100%	100%	100%	100%

CBU-87

Process cost coverage = 28%   Average unit cost =0.010545 ($M)

WORK BREAKDOWN STRUCTURE	Bomblet	Dispense	Assemble	LAFT	Sensor	Container	Eng
Percent of unit cost	33%	35%	14%	0%	10%	7%	1%
SUBSYSTEM COST BREAKDOWN							
PURCHASED MATERIALS	80%	82%	7%	67%	88%	88%	26%
MANUFACTURING PROCESSES							
M&S Forming	4%						
M&S Treatment							
M&S Material Removal							
M&S Finishing							
M&S Joining							
M&S Assembly			79%				
E&E Fabrication							
E&E Assembly							
Chemicals Processing							
Test/Inspection	3%	3%	1%	21%	0%	0%	10%
Other							
MANUFACTURING SUPPORT PROCESSES							
Materials Handling			1%				
Manufacturing Engineering		1%	1%				
Production Management	1%	1%			0%	0%	52%
OTHER OVERHEAD	12%	12%	12%	11%	12%	12%	12%
Subsystem Totals	100%	100%	100%	100%	100%	100%	100%

EPLRS

Process cost coverage = 70% Average unit cost = 0.165 ($M)

WORK BREAKDOWN STRUCTURE	Radio	Readout	Display	Station	Other
Percent of unit cost	65%	5%	5%	20%	5%
SUBSYSTEM COST BREAKDOWN					
PURCHASED MATERIALS	30%	40%	40%	20%	53%
MANUFACTURING PROCESSES					
M&S Forming	1%	1%	1%		1%
M&S Treatment	1%	1%	1%		1%
M&S Material Removal	1%	1%	1%		2%
M&S Finishing	1%	1%	1%		1%
M&S Joining					
M&S Assembly				10%	1%
E&E Fabrication	2%	1%	1%		
E&E Assembly	10%	2%	3%	6%	
Chemicals Processing					
Test/Inspection	5%	3%	5%	6%	
Other					1%
MANUFACTURING SUPPORT PROCESSES					
Materials Handling	15%	10%	10%	25%	3%
Manufacturing Engineering	7%	7%	7%	4%	2%
Production Management	7%	8%	8%	11%	10%
OTHER OVERHEAD	20%	25%	25%	20%	25%
Subsystem Totals	100%	100%	103%	102%	100%

MSE

Process cost coverage = 47%

Average unit cost = 71 ($M)

WORK BREAKDOWN STRUCTURE	Facility	Truck	Elec.	Other
Percent of unit cost	37%	8%	50%	5%
SUBSYSTEM COST BREAKDOWN				
PURCHASED MATERIALS	30%	70%	65%	70%
MANUFACTURING PROCESSES				
M&S Forming	3%			
M&S Treatment	1%			
M&S Material Removal	2%			
M&S Finishing	1%	5%		5%
M&S Joining	1%			
M&S Assembly	6%			
E&E Fabrication	2%			
E&E Assembly	1%			
Chemicals Processing				
Test/Inspection	3%	5%	10%	5%
Other				
MANUFACTURING SUPPORT PROCESSES				
Materials Handling	15%	5%	10%	5%
Manufacturing Engineering	10%	5%	5%	5%
Production Management	10%	5%	5%	5%
OTHER OVERHEAD	15%	5%	5%	5%
Subsystem Totals	100%	100%	100%	100%

PLS

Process cost coverage = 34%

Average unit cost =0.248816 ($M)

WORK BREAKDOWN STRUCTURE	
	Vehicle
Percent of unit cost	100%
SUBSYSTEM COST BREAKDOWN	
PURCHASED MATERIALS	66%
MANUFACTURING PROCESSES	
M&S Forming	1%
M&S Treatment	
M&S Material Removal	2%
M&S Finishing	0%
M&S Joining	1%
M&S Assembly	1%
E&E Fabrication	
E&E Assembly	0%
Chemicals Processing	
Test/Inspection	0%
Other	
MANUFACTURING SUPPORT PROCESSES	
Materials Handling	4%
Manufacturing Engineering	3%
Production Management	3%
OTHER OVERHEAD	18%
Subsystem Totals	100%

SINCGARS

Process cost coverage = 47%

Average unit cost = 0.01 ($M)

WORK BREAKDOWN STRUCTURE	
	System
Percent of unit cost	100%
SUBSYSTEM COST BREAKDOWN	
PURCHASED MATERIALS	53%
MANUFACTURING PROCESSES	
M&S Forming	
M&S Treatment	
M&S Material Removal	1%
M&S Finishing	
M&S Joining	
M&S Assembly	
E&E Fabrication	
E&E Assembly	13%
Chemicals Processing	
Test/Inspection	4%
Other	
MANUFACTURING SUPPORT PROCESSES	
Materials Handling	5%
Manufacturing Engineering	4%
Production Management	3%
OTHER OVERHEAD	17%
Subsystem Totals	100%

FDS

Process cost coverage = 53% Average unit cost = 441.2 ($M)

WORK BREAKDOWN STRUCTURE	Cables	Clusters	Elec.
Percent of unit cost	27%	71%	2%
SUBSYSTEM COST BREAKDOWN			
PURCHASED MATERIALS	61%	42%	41%
MANUFACTURING PROCESSES			
M&S Forming	7%	1%	1%
M&S Treatment			1%
M&S Material Removal			1%
M&S Finishing			1%
M&S Joining		1%	1%
M&S Assembly		6%	2%
E&E Fabrication			4%
E&E Assembly		1%	9%
Chemicals Processing		1%	1%
Test/Inspection	1%	3%	4%
Other			
MANUFACTURING SUPPORT PROCESSES			
Materials Handling		5%	4%
Manufacturing Engineering		12%	8%
Production Management		9%	4%
OTHER OVERHEAD	31%	19%	18%
Subsystem Totals	100%	100%	100%

M864 PROJECTILE (155mm)

Process cost coverage = 41%   Average unit cost =0.000837 ($M)

WORK BREAKDOWN STRUCTURE	Body	Burner	Base	SubMun.	Pack	Fuze	Other
Percent of unit cost	24%	16%	4%	35%	8%	10%	3%
SUBSYSTEM COST BREAKDOWN							
PURCHASED MATERIALS	35%	60%	100%	75%	20%	60%	100%
MANUFACTURING PROCESSES							
M&S Forming	9%	2%		1%			
M&S Treatment	7%	2%		2%			
M&S Material Removal	14%	2%		4%			
M&S Finishing	4%	2%		3%			
M&S Joining							
M&S Assembly		15%			40%	20%	
E&E Fabrication							
E&E Assembly							
Chemicals Processing	1%			2%			
Test/Inspection	3%	4%		3%	20%	5%	
Other							
MANUFACTURING SUPPORT PROCESSES							
Materials Handling	7%	3%		5%	10%	5%	
Manufacturing Engineering	6%	1%			2%	1%	
Production Management	6%	1%			2%	1%	
OTHER OVERHEAD	8%	8%		5%	6%	8%	
Subsystem Totals	100%	100%	100%	100%	100%	100%	100%

AEI Heat Tank Ammo

Process cost coverage = 60%

	Fuze	Proj.	Liner	Prop.	I&A
WORK BREAKDOWN STRUCTURE					
Percent of unit cost	20%	20%	10%	25%	25%
SUBSYSTEM COST BREAKDOWN					
PURCHASED MATERIALS	50%	30%	50%	76%	
MANUFACTURING PROCESSES					
M&S Forming		10%	35%		
M&S Treatment		20%	5%		
M&S Material Removal		15%	2%		2%
M&S Finishing		5%	2%		10%
M&S Joining					75%
M&S Assembly		10%		19%	
E&E Fabrication	15%				
E&E Assembly	25%				
Chemicals Processing					
Test/Inspection	10%	10%	6%	5%	13%
Other					
MANUFACTURING SUPPORT PROCESSES					
Materials Handling					
Manufacturing Engineering					
Production Management					
OTHER OVERHEAD					
Subsystem Totals	100%	100%	100%	100%	100%

AEI Kinetic Ammo

Process cost coverage = 66%

WORK BREAKDOWN STRUCTURE	Pen.	Sabot	I&A	Prop.
Percent of unit cost	20%	30%	25%	25%
SUBSYSTEM COST BREAKDOWN				
PURCHASED MATERIALS	30%	30%		76%
MANUFACTURING PROCESSES				
M&S Forming	25%	35%		
M&S Treatment	25%			
M&S Material Removal	10%	15%	2%	
M&S Finishing	5%	5%	10%	
M&S Joining		2%	75%	
M&S Assembly		2%		19%
E&E Fabrication				
E&E Assembly				
Chemicals Processing				0%
Test/Inspection	5%	5%	13%	5%
Other				
MANUFACTURING SUPPORT PROCESSES				
Materials Handling				0%
Manufacturing Engineering				0%
Production Management				0%
OTHER OVERHEAD				0%
Subsystem Totals	100%	94%	100%	100%

APPENDIX C

LIST OF MANTECH GAPS

DOD MANUFACTURING TECHNOLOGY ISSUES
LISTED BY PROCESS AND COMMODITY

M&S Forming

Aircraft

ADV OXI RESIST ALLOY POWD	F
ADVANCED COMPOS PROC	F
ADVANCED TOOLING	F
ADVANCED TRANSPARENCIES	F
Aluminum Lithium SPF	I
COMPOSITES MANUFACTURING PRODUCTIVITY FACILITY	F
COST EFFEC. MFG. OF AIRFRAME STR. & COM	F
Compglas for IHPTET Engines	I
Complex Shape Thermoplastics	F
Composite Electronic Packaging Structures	I
Composite Metal & Ceramic Components	I
Composite Repair	I
Conductive Composites for Avionics Housings	I
Continuous Plasma Spray MMC Monotape	U
DMATS	F
DMATS	F
Durable composites lay-up tooling	I
Expert System for Autoclave Loading	I
F-15 Thermoplastic Doors	U
FAB PROCESS FOR HIGH TEMP PM ALUMINUM IMPELLERS	F
Fiber Placement	I
High Formability Thermoplastic Structures	I
High Temperature Al Rotating Components	I
High Temperature Filament Winding	I
IMPROVED AIRFRAME MANUFACTURING TECHNOLOGY	F
INTGRATED COMPOSITES CNTR	F
Injection molding of thermoplastics & composites	I
Laser Consolidation of Thermoplastics	F
Low Cost Composites Manufacturing	F
Low Cost Fabrication of Alpha-2 Metal Matrix Composites	F
Low observables composite design guide	I
Low-observable Airframe Structures	I
Manufacturing of Thermoplastic Composite Prefered Spare	F
Matrix Composite Ring Manufacturing	U
Multi-directional Fiber Pre-forms	I
PREM QUAL TI ALLOY DISK	F
Polycarbonate manufacturing of windshields	I
Pultrusion of Large Components	I
Recycling of Composite Pre-preg Scrap	I
Resin Transfer Molding	I
Resin Transfer Molding	I
Rotary Wing Precision Gear Manufacturing	I
Selective Reinforcement of Injection Molding	I
Semi-Solid Metal Molding	I

Letter Codes: I = Identified in cost driver data collection
F = Funded MT project
U = Unfunded MT project

DOD MANUFACTURING TECHNOLOGY ISSUES LISTED BY PROCESS AND COMMODITY

M&S Forming	
Aircraft	
Spray Forming of Superalloy Structures	I
Super-plastically-formed Aluminum Lithium	I
TITANIUM ALUMINIDE XD COMPOSITE	F
Thermoplastic Structures Manufacturing	I
Thermoplastics Compression Molding	I
Thin composite structures	I
Titanium Aluminide XD Composites	I
Missiles	
Autorolling of Gears	I
COMPOSITE TOOLING FOR OPTICAL FABRICATING PROCESSING	F
CONTINUOUS PROCESS FOR FIRE CONTROL OPTIC GLASS	F
Composites for Oxident Tanks	I
Fiber Winding of Torpedo Shells	I
High Temperature Filament Winding	I
Laser Metalworking	I
MT for Carbon-Carbon Components for Expendable Engines	F
Missile Afterbody Composite Components	I
Monolithic Titanium Aluminide Structures	F
NEAR-NET SHAPE SAPPHIRE DOMES	F
NET SHAPE FINISHING OF GEARS BY AUSROLLING	F
Precision Molding of Plastic Parts	I
Production and Casting of Barium Strontium Titanate	F
Pultrusion of Large Components	I
Resin Transfer Molding	I
SM ENG COMP COMPRES ROTOR	F
Thermoplastics Compression Molding	I
Ships	
Alternate Antenna Materials	I
Laser Fabrication	I
Laser Valve Cladding	I
NAVY METALWORKING TECHNOLOGY CENTER	F
PLASMA ARC-CNC MACHINING TECHNOLOGY INTEGRATION	F
Plasma Spray cell Repair	I
Powder Metallurgy	I
Spray Forming of Metal Components and Piping	I
WTCV	
Method for Fabricating Composite Gun Tubes	F
Precision Molding Optic Glass	F
Tracked Vehicle Tread Manufacturing	F
Ammo	
Composite Sabot Molding	F

Letter Codes: I = Identified in cost driver data collection
F = Funded MT project
U = Unfunded MT project

DOD MANUFACTURING TECHNOLOGY ISSUES
LISTED BY PROCESS AND COMMODITY

M&S Forming	
Ammo	
Precision Processes for Ammunition	I
Other	
Application of Artificial Intelligence to Stereolithogr	F
Metal Forming Simulation	F
Ordered Polymer Films	F
M&S Treatment	
Aircraft	
Hazardous chemical alternatives	I
ROBOTIC SHOT PEENING	F
Missiles	
Hazardous chemical alternatives	I
M&S Material Removal	
Aircraft	
ADVANCED BALANCING WITH LASER MACHINING - PHASE II	F
High Speed Airfoil Machining	F
High Speed Drilling of High Temperature Alloys	I
Improved Broaching UDIMET 720	F
MACHINING INITIATIVES FOR AEROSPACE SUBCONTRACTORS	F
Precision Machining of Small Wavelength Systems	I
Ships	
FLEXIBLE MANUFACTURING SYSTEMS	F
ICAMP	I
Integrated Manufacturing of Propulsor Blades	I
PROPELLER MACHINING SYSTEM	F
Propeller Adaptive Machining System	I
SENSOR-BASED CONTROL OF MANUFACTURING PROCESSES	F
WTCV	
FLEXIBLE MACHINING SYSTEM-RIA (CAM)	F
Ammo	
AMMO DEMILITARIZATION WITH ABRASIVE WATER JET	F
M&S Finishing	
Aircraft	
ADVANCED REFURBISHMENT OF ENGINE PARTS	F
Advanced Environmentally Safe Anodizing System for Airc	U

Letter Codes: I = Identified in cost driver data collection
F = Funded MT project
U = Unfunded MT project

DOD MANUFACTURING TECHNOLOGY ISSUES
LISTED BY PROCESS AND COMMODITY

M&S Finishing
  Aircraft
    Diamond Film Passivation & Thermal Management I
    Dual Alloy Turbine Disc Advanced Manufacturing Processe I
    E-coating as an Alternative to High VOC Paints I
    Ion Implantation as an Alternative Coating Process I
    Powder Coating as an Alternative to High VOC Paints I
    Powder Coating as an Alternative to High VOC Paints I
    Repair of Thermal Barrier Coatings I
    Thin-wall Coatings of Ti and Ni Alloys I
    Water-based Cleaning System I

  Missiles
    CAM MACHINE FOR PRISMS F
    CRITICAL PARAMETERS OF LENS GRINDING AND POLISHING F
    Cadmium Plating Alternatives I
    Cleaning of Precision Parts I
    Diamond Film Bearings I
    Diamond Film Passivation & Thermal Management I
    Diamond IR Domes I
    Electronics Chassis Coating I
    OPTICAM SPHERICAL AND FINISHING SYSTEM AND EQUIP F

  Ships
    Corrosion I

  WTCV
    APPL OF REFRACTORY + OTHER COATINGS BY THE SPUTTERING T F
    Cadmium Plating Alternatives I
    Chrome Plating Alternatives I
    Chrome Plating Process Control Information System (CAM) F
    IMPROVED FABRICATION OF RECOIL WEAR SURFACES F
    Metal Cleaning Alternatives to CFCs I
    SMALL ARMS WEAPONS NEW PROCESS PRODUCTION TECHNOLOGY F

  Ammo
    ENVIRONMENTALLY ACCEPTABLE MATERIAL TREATMENT PROCESSES F

  Other
    RUGATE FILTERS F

M&S Joining
  Aircraft
    AIRCRAFT WET RIVETING & FAYED SURFACE SEALING VS. EMI F
    Blade/Vane Repair F
    Manufacturing Technology for Blade Repair F

Letter Codes: I = Identified in cost driver data collection
F = Funded MT project
U = Unfunded MT project

DOD MANUFACTURING TECHNOLOGY ISSUES
LISTED BY PROCESS AND COMMODITY

M&S Joining	
Aircraft	
Process Control for Adhesives	F
Missiles	
Auto Optical Fiber Adhesive Application	F
Ships	
Advanced Welding Electrodes	I
Composite Materials Joining	I
Electroslag	I
HY-130 Steel Welding	I
Homopolar Pulsed Welding	I
LASER ARTICULATING ROBOTIC SYSTEM (LARS)	F
Optimized Weldment for HY130 Steel	I
ROBOTIC ADAPTIVE WELDING SYSTEM (RAWS)	F
SHIPBUILDING MANUFACTURING TECHNOLOGY (MT) PROGRAM	F
WELD EXCEL	I
YAG Laser Welding	I
WTCV	
ALL BONDED PRODUCTION TECH FOR PRODUCTION OF MEDIUM DUT	F
Welding Processes and Controls	I
Ammo	
Band Welding Automation (4904)	F
Other	
ROBOTIC CONTROL OF LASER WELDING	F
M&S Assembly	
Aircraft	
ADVANCED ROBOTIC AIRFRAME ASSEMBLY TECHNOLOGY	F
AUTO AIRFRAME ASSEMBLY/N	F
Advanced Insulation	F
Automated Airframe Assembly Program	F
Automated assembly of aircraft structures	I
Refurbishment of Engine Parts	I
Sensors	I
Missiles	
MANUFACTURING TECHNOLOGY FOR MISSILE SEEKER DEWARS	F
Ships	
Light Weight Antenna Structures	I
Light Weight Structures	I

Letter Codes: I = Identified in cost driver data collection
F = Funded MT project
U = Unfunded MT project

DOD MANUFACTURING TECHNOLOGY ISSUES
LISTED BY PROCESS AND COMMODITY

M&S Assembly	
Ships	
NSRP	I
Ammo	
MECHANIZATION OF ASSY OPERATIONS FOR MICLIC	F
E&E Fabrication	
Aircraft	
ADV DATA/SIGNAL PROCESS	F
Active matrix liquid crystal displays	I
Advanced Sensors for Epitaxial Growth	F
Bare Die TAB Bonding	I
Custom TAB Fabrication	I
Design standards for surface mount devices in LRUs	I
Hi-Definition Display	F
Increase Focal Plane Array Yields	I
Increase Yield of GaAs Crystals	I
Integrated Manufacturing for Electronic Packaging	I
Low Cost GaAs Wafer	F
Low Cost/Low Profile Compliant Lead	I
Manufacturing Technology for Radar Transmit/Receive	F
Opto-Electronics	F
SOLID STATE MICROWAVE SYS	F
T/R Module Second Award	U
TC Substrates	I
TRANSMIT RECEIVE MODULE	F
Missiles	
75mm Cadmium Zinc Telluride	F
94 GHZ MILLIMETER WAVE TRANSCEIVER	F
COMPOSITES FOR PASSIVE THERMAL MANAGEMENT	F
COMPOSITES FOR PASSIVE THERMAL MANAGEMENT	F
Design standards for surface mount devices	I
Electro-optic Components Advanced Manufacturing Process	I
FIBER OPTIC MICROCABLE	F
Fiber Optic Micro-cable	I
GaAs Manufacturing Processes	I
HIGH RESOLUTION PATTERNING	F
High Thermal Fibers	I
High Thermal Pitch Fibers	I
IC Packaging and Sealing	I
IR Imaging	F
Inertia Switches	I
Integrated Circuit Contact Fuze	I
Ion Plating Superconductor	I

Letter Codes: I = Identified in cost driver data collection
F = Funded MT project
U = Unfunded MT project

DOD MANUFACTURING TECHNOLOGY ISSUES
LISTED BY PROCESS AND COMMODITY

E&E Fabrication	
Missiles	
Pressure Transducers	I
ROBOTIZED WIRE HARNESS ASSEMBLY SYSTEMS ENHANCEMENTS	F
Solenoids	I
Solid State Fire Control Switch	I
Submicron Resist	I
TI CARBIDE SUBSTRATE FOR SI CARBIDE IMPATT DEVICES	F
Thermoplastic Radomes	F
Ships	
Digital Multichip Modules	I
MOS-Controlled Thyristor MCT	I
Solid State T/R Modules	I
Thick Film Process	I
Ammo	
MT FOR INFR SENSORS SFW	F
Other	
Active Matrix Liquid Crystal Displays	F
BUB MEM PERIPHERAL ELECTR	F
Foundry Fabrication of MIMIC Chips	U
GA AS/GE SOLAR CELLS	F
GaAs/Ge Solar Cell Panels	F
HGCDTE DETECTOR ARRAYS	F
MICROELEC MFG S AND T	F
MT for Ferroelectric Random Access Memories	U
MT for Rugate Thin Films	U
Man Science for Reliability Without Hermeticity	F
Production Methods for Optical Waveguides	F
SI-ON-INSULATOR WAFERS	F
Superconductivity Technology	F
E&E Assembly	
Aircraft	
Aqueous Flux Cleaning	I
CIRCUIT CARD ASSEMBLY & PROCESSING SYSTEM (CCAPS)	F
Electronics Packaging to Support Sensor Fusion	I
Fiber Optic Backplane Interconnect	I
Fiber Optic Terminations	I
Flexible Forming Tools	I
Fluxless Solder	I
Hazardous chemical alternatives	I
Hot Bar Soldering	I
Hybrid Antenna/Waveguide Arrays	I

Letter Codes: I = Identified in cost driver data collection
F = Funded MT project
U = Unfunded MT project

DOD MANUFACTURING TECHNOLOGY ISSUES
LISTED BY PROCESS AND COMMODITY

E&E Assembly	
Aircraft	
RF transmission line Design standards	I
Repair of Surface Mount Devices	I
Robotic Placement	I
Robotics Work Cell for Lead Preparation	I
Vapor Phase Expert System	I
Zero Force Interconnect	I
Missiles	
3-D Packaging	I
Connector Quality	I
Enhancements to the Automated Hybrid Package Sealing Sy	F
Hazardous chemical alternatives	I
Heat Removal During PC Board Assembly	I
IMU - ROBOTIC DEVELOPMENT	F
INTEGRATED MANUFACTURING FOR ELECTRONIC PACKAGING	F
Laser Gyro Replacement for GRU	I
Micro-CIM	I
Photodetector Arrays in Optical Circuits	I
Repair of Surface Mount Devices	I
Rigid Flex Connectors	I
STANDARD ADVANCED DEWAR ASSEMBLY (SADA)	F
Soldering of Surface Mount Devices	I
Stacking Connector Alternatives	I
VHSIC MULTICHIP PACKAGING	F
VHSIC Packaging	I
Ships	
Active Phased Array Structure	I
Aqueous Flux Cleaning	I
Automated Tuning of Microwave Devices	I
Compartmentalized Analog Manufacturing	I
Connector Quality	I
Laser Soldering	I
Solder Mask Development	I
Solderability Analysis Tool	I
Solid State T/R Modules	I
Ammo	
INTEGRATED CIRCUIT CONTACT FUZE	F
Other	
Desolder/Solder PWA	F
Electronic Packaging Initiative	F
Fiber Optic Handling, Routing, & Stripping	I
Fiber Optic Precision Splicing	I

Letter Codes: I = Identified in cost driver data collection
F = Funded MT project
U = Unfunded MT project

DOD MANUFACTURING TECHNOLOGY ISSUES
LISTED BY PROCESS AND COMMODITY

E&E Assembly	
Other	
INSTALL OF A REPAIRABLE UV CURE CONFORMAL COAT SYS	F
PWB Assembly	F
ROBOTIC CONTROL OF PLATING	F
Solder/Desolder of Printed Wiring Assembly Components	F
Soldering Technology	F
T/R Modules	I
X-Ray Laminography	F
Chemical Processes	
Aircraft	
ADVANCED PROCESSING TECHNIQUES FOR ENERGETIC MATERIALS	F
Low Observable Coatings	F
Maintenance-Free Battery/Charger System	F
Man Tech for Large Aircraft Robotic Paint Stipping Syst	F
Missiles	
ADVANCED BINDER	F
AUTOMATED PROCESSING OF LITHIUM BATTERIES	F
Advanced Binder Material	F
Durable Coatings for Infrared Windows	F
Fine Particle Insensitive Pyrotechnic Material	I
Ammo	
Beken Mixer Development	I
Fluidized Bed Processes	I
Incineration Technology	I
NITRAMINE PROPELLANT PROCESSING	F
NITROGUANIDINE PLANT UNIT OPERATION PRODUCTIVITY IMPROV	F
Pilot Chemical Management System	I
Process Control of Water & Slurry Pre-mix	I
Other	
HEAVY DUTY PREFABRICATED MEMBRANE SURFACING	F
MANUFACTURING TECHNOLOGY FOR ADVANCED SORBENTS	F
Plating Bath Rejuvination	F
Test/Inspection	
Aircraft	
ADVANCED INSPECTION & REPAIR TECH FOR REWORK APPL.	F
Automated NDI	I
Dimensional Gauging of Engine Components	F
HOLOGRAPHIC WAFER INSPECT	F
Inspect & Repair Technology	I

Letter Codes: I = Identified in cost driver data collection
F = Funded MT project
U = Unfunded MT project

DOD MANUFACTURING TECHNOLOGY ISSUES
LISTED BY PROCESS AND COMMODITY

Test/Inspection	
Aircraft	
Integrated Avionics Functional Test	I
NDE SYSTEM FOR RFC	F
NDI of Airfoils	I
NDI of Thick Sections	I
Non-Destructive Evaluation of Bond Quality	F
RF Transmission line test standards	I
Missiles	
Automated Fault Diagnostics	I
Automated Inspection	I
Automated Inspection	I
Electronic Stress Screening	I
Inspection of Microelectronic Devices	I
MAGNETO-OPTICAL MAPPER F/SCREENING OF SEMICONDUCTOR WAF	F
Non-Destructive Detector Array Testing	F
Optical Inspection Refinements for Printed Wiring Board	I
Propellant Analysis by Infrared Spectroscopy	F
SOLID-STATE VOLTAGE CALIBRATION SYSTEMS	F
Ships	
Acoustic Emission Inspection	I
Automated Fault Diagnostics	I
Ultrasonic Inspection Imaging System	I
WTCV	
AUTO INSPECTION + PROCESS CONTROL OF WEAPONS PARTS	F
AUTOMATED CROSS-DRIVE TRANSMISSION TEST STAND	F
AUTOMATED INSPECTION OF RECOIL COMPONENTS	F
Dye Penetrant Alternatives	I
Ultrasonic Tube Wall Thickness	F
Ammo	
AUTOMATED CUP INSPECTION	F
Auto Image Recognition and Manipulation	F
REMOTE AUTOMATIC SAMPLING OF NITROGLYCERIN (NG)	F
Other	
AUTO TESTING - MMICS	F
Automated Inspection	I
High Pressure Test	I
LIGHTWEIGHT CONTINUITY AND HIGH POTENTIAL TESTING	F
MT for NDI Solder Joint Inspection	F
Materials Testing Technology (MTT) Program	F
Multi-Axis Vibration Testing	F
Non-Destructive Evaluation of Printed Wiring Assembly	F

Letter Codes: I = Identified in cost driver data collection
F = Funded MT project
U = Unfunded MT project

DOD MANUFACTURING TECHNOLOGY ISSUES
LISTED BY PROCESS AND COMMODITY

Test/Inspection	
Other	
On-line verifcation of Camoflaged & Suppressant Materia	I
Rep Tech for Infrared Imaging of Phased Array Radiation	U
Segmentation of ATE Control Programs	F
Other	
Aircraft	
AUTOMATED PLASTIC MEDIA BLASTING CELL	F
Blade/Disc Dissassembly Machine	F
Composite Engine Repair Center	F
Composite Manufacturing Cost Handbook	F
Concurrent Engineering for Advanced Nozzles	F
Conformal Coating Compatibility	I
DESEALING	F
FLEXIBLE REPAIR CENTER	F
MT FOR ADV PROP MATLS	F
Manufacturing Technology for Conventional Ti MMC Shapes	U
Producible Nozzle Structures Manufacturing	F
STATIC & ACCESSORY REPAIR	F
Missiles	
AMRAAM MMCV Gas Generator Case	F
Advanced Ramjet Structures Manufacturing	F
MT for Producable Missile Wings	F
Man Science for Carbon-Carbon Composites	F
Manufacturing Technology for Fiber Optic Gyro Assembly	U
Other	
ASEPTICALLY PROCESSED TRAY PACK AND MRE COMPONENTS	F
Active-Matrix LCD	F
Advanced Metal Matrix Foil Manufacturing	F
Application Validation Center	F
CIM, Protocol and Logistics Cell	F
COMPOSITE CUCV/HMMWV COMPONENTS REPAIR	F
Clothing, Tentage, and Parachute processes	I
Computer Integrated Processing	F
Electronics Manufacturing Process Improvement	F
Electronics Manufacturing Process Improvement II	F
Electronics Mfg. Process Improvement	F
Engineering Information Systems for ALC	U
Enterprise Integration Program	F
Feature Recognition for Prod Def using Knowledge Based	F
Framework Support	F
Hybrid Composite Pressure Vessel	F
Integrated Tool Kit and Methods	F

Letter Codes: I = Identified in cost driver data collection
F = Funded MT project
U = Unfunded MT project

DOD MANUFACTURING TECHNOLOGY ISSUES
LISTED BY PROCESS AND COMMODITY

Other	
Other	
Integrated Validation Environment	F
MANUFACTURING TECHNOLOGY FOR ENZYME FOR DETECTION SYSTE	F
MMT FOR ANTIBODIES FOR DETECTION SYSTEMS	F
MT Special Advanced Studies	F
MT for Automation and Integration Program	U
MT for Integrated Process Applications Manager	F
Machine Tool Sensor Improvements	F
Man Meth for Spare Parts Reprocurement & Production Sup	F
Man Tech for Machine Tool Initiatives	F
ManTech for Microencapsulation of Decontaminating Agent	F
Manufacturing Technology Special Studies	F
Pathogen & Toxin Antibodies	F
Performance Measurement for Integrated Technology	F
Product Data Application Subset for Electronics	F
Product Data Application Subsets for Composites	F
Propulsion Initiative	F
Rapid Prototype Development System	F
Sensor Based Manufacturing	F
T\R Modules	F
Technology Cost and Risk Assessment	F
Thermoelectric Cooler	U
Vacuum Packaging of Chemical Protective Suits	I
Materials Handling	
Ships	
Virtual Chip Kitting	I
Manufacturing Engineering	
Aircraft	
CAD and Analysis of Microwave Integrated Circuits	I
DIGITAL PROD/L	F
DIGITAL PROD/N	F
INTEL MACH WKSTN	F
KNOWLEDGE INTG DES SYS	F
MT FOR ADV PROP MATLS	F
MT FOR HIGH VOLTAGE P/S	F
NCMS	F
NEXT GEN CONTROLLER	F
Missiles	
OPTICAL DESIGN ENGR USING GENERATIVE PROCESS PLNG + COS	F
Production Engineering Tools	F

Letter Codes: I = Identified in cost driver data collection
F = Funded MT project
U = Unfunded MT project

DOD MANUFACTURING TECHNOLOGY ISSUES
LISTED BY PROCESS AND COMMODITY

Manufacturing Engineering	
Ships	
INTELLIGENT WELD PROCESS PLANNER FOR FLEX WELD FAB	F
Ammo	
Fracture Mechanics of Cast Iron Projectiles	I
Other	
Extensions to VHSIC Hardware Description Language (VHDL	I
SURFACE MODELING CLOTHING DESIGN COMPUTER	F
Production Management	
WTCV	
PRODUCTION SIMULATION	F
Other	
Engineering Information System	F
Other Overhead	
Other	
DATA AUTO PROCESSOR	F
Enterprise Integration Program	F
Framework Support	F
Integrated Design System	F
PDES Application Protocol Suite Projects	F

Letter Codes: I = Identified in cost driver data collection
F = Funded MT project
U = Unfunded MT project